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Nitrate Fertilization and Keeping Quality of Apple Fruits

Chemical, Physiological, and Storage Studies

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CONTENTS

Introduction 3

The Orchards 4

Literature 5

Internal Breakdown 9

Yield and Growth in Stayman Orchard 9

Chemical and Physiological Studies 10

  Methods 10

  Results 20

Storage Investigations 42

  The Stayman Orchard 42

  The West Orchard 43

  The East Orchard 45

Discussion 47

Summary 49

Summary Tables 51

Literature Cited 65

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NITRATE FERTILIZATION AND KEEPING QUALITY OF APPLE FRUITS

Chemical, Physiological, and Storage Studies

J. H. GOURLEY AND E. F. HOPKINS

The fruit grower must contend with several types of deterioration of fruit after it is harvested and placed in storage. The kind and amount of loss from this source varies with such factors as the variety, the season, the soil factors, time of picking, and methods of handling. Some of these troubles are due to definite pathogenes, while others appear to be the result of physiological disturbances and may take diverse forms. It is with these latter types of deterioration that this paper deals, particularly with the trouble referred to as "breakdown", and with the role that fertilizer treatments have been reported to play in inducing them.

Physiological breakdown has been reported from nearly all the large fruit-growing areas and it has become so serious in some of them as to warrant investigations of the probable cause and remedy. The inference had been drawn by many experienced fruit growers and dealers that breakdown in transit or storage was due to applications of nitrogen fertilizers and, hence, raised the question as to whether other elements than nitrogen should not be supplied to the orchard or some modification made in the prevailing practice of using nitrogen alone as a soil treatment. Scientific literature, as referred to later, also gives some support to the contention that relatively high nitrogen content of fruit would result in earlier deterioration than would a relatively low content of this element. There has been a tendency in some sections to discriminate in price against fruit from orchards that had been treated with nitrogen fertilizers only.

As a result of this situation the Department of Horticulture has undertaken a series of experiments to determine whether, under the conditions prevailing on their grounds, applications of Chilean nitrate of soda result in breakdown or other troubles which should preclude its use or justify a combination of this salt with those carrying phosphorus and potassium. No special study has been made of the diseases themselves, but rather of their occurrence following specific treatments.

The work here reported is divided into three different phases; namely, (1) the effect of Chilean nitrate upon the growth and yield of the trees (except in the orchards which are just coming into bearing and where the yield records are not significant); (2) the chemical and physiological studies of the fruit; and (3) the storage tests of the fruit from the several treatments.

THE ORCHARDS

Three different blocks of orchards have been used in these studies, with some minor work in two other ones. One, known in this work as the West orchard, was planted in 1922 and has been continuously in the tillage-cover crop system of management. The block consists of approximately 4½ acres with the long rows (29 trees including fillers) running north and south and the short rows (15 trees including fillers) east and west. The soil is Canfield silt loam, which had been used for growing farm crops prior to the planting of the orchard. It had been manured and fertilized each year but no definite record of amounts is available. It contains the varieties Stayman Winesap, Grimes Golden, Jonathan, and McIntosh, and the rows of each occur in the order named, running from east to west, and are repeated in that order throughout the orchard. The permanent trees are 38 by 40 feet apart with fillers in both directions. The latter varieties are Stayman Winesap, Grimes Golden, Paragon, McIntosh, and Winesap. The cover crops have included, in different years, buckwheat, oats and vetch, vetch, and rye; thus both legumes and non-legumes have been used. The trees have made a very satisfactory growth and have come into bearing relatively early, although the yield has been reduced considerably by spring frosts.

In this orchard the treatments of Chilean nitrate varied as to time of application, and all treated plots received the same total amount. No "essential" element other than nitrogen has been added. Every alternate permanent row received a "normal" application of Chilean nitrate as a control, and one of the permanent rows has received no fertilizer.

As used in this paper, the expression "normal" nitrate treatment refers to an arbitrary amount of ¼ pound for each year of the tree's age, thus increasing from year to year. It is realized that there could be no normal amount but some arbitrary standard must be adopted for convenience, and this amount is commonly used in commercial orchards in Ohio.

The East orchard was planted the same year as the one described above and was cultivated during the period of these experiments; the cover crops were the same as in the West orchard. The East orchard consists of Baldwin and Stayman Winesap for permanent trees, planted 40 by 40 feet, and filler trees of Wealthy and Stayman Winesap, which are planted in the rows running north and south only. These trees have likewise made a satisfactory growth, but the Baldwin variety has been somewhat tardy in production.

The treatments in this orchard vary from those described above in that they are all applied at the same time, in early spring, and in that they consist of Chilean nitrate used alone and in combination with phosphorus or potassium or both. As in the above orchard every alternate row of permanent trees was treated with the "normal" amount and there was one row which received no fertilizer treatment. The amounts of all salts were increased proportionately each year as indicated for nitrogen in the West orchard.

The Stayman orchard is a small block of 50 trees consisting entirely of Stayman Winesap, although in close proximity to other orchards, thus providing adequate cross-pollination. It was planted in 1915 and has been continuously in sod. No fertilizer or manure was applied to any of the trees prior to 1922 when certain of them were used for differential treatments with Chilean nitrate. The untreated trees of this orchard are typical of trees in this region which are supplied with insufficient nitrogen; that is, they are making an unsatisfactory growth, give low average yield, and the leaves are small and yellowish in color. Certain of the treated trees have received much larger amounts of nitrate than is customary in Ohio, since 1922. Such an orchard furnishes excellent material for the purposes of these studies and more analyses have been made from the fruit of this orchard than the others. Also, the growth and yield data are of greater value than those from young orchards which are just coming into commercial bearing and are therefore included as representative of a sod orchard.

LITERATURE

The effect of nitrogen fertilizers on the color and keeping quality of apples and peaches, grown on light sandy soils, clay loam, and the red shale soils of western Maryland, has been studied by Degman (10). Comparisons were made with light and heavy applications of nitrate of soda and sulphate of ammonia, both used alone and in combination with superphosphate or in a complete fertilizer. In one of the orchards of Stayman Winesap which was not cultivated and hence had made a striking response to the nitrogen treatments, it was observed that the fruit from the seven untreated plots softened more in every case than the nitrated fruits. In general, he concludes that applications of nitrogen fertilizers have caused no consistent change in the keeping quality of apples or peaches, as indicated by pressure tests and storage counts. "However, when orchard practices, as pruning, soil management, thinning, irrigation, etc., are unwisely administered in connection with the use of nitrogen, resulting in the production of excessively large fruit, or when immature fruit is harvested, there will be a decrease in keeping quality, which is often incorrectly ascribed to the use of nitrogen."

Similar studies on the effect of fertilizers on yield, color, size, and storage quality of apples have been reported by Magness and Overly (29). Under the conditions of their tests, commercial loss of fruit in storage was due mostly to physiological breakdown. Pressure tests of the fruit were made at intervals during the storage season and there was no significant variation in the rate of softening which could be attributed to fertilizer treatment. While no definite conclusions were drawn after 3 years' work, it was noted that fruit receiving nitrogen was somewhat poorer in color, and color was not improved by adding superphosphate or potash fertilizers to the nitrogen, and further, that there had been no measurable difference in rate of softening due to fertilizer treatment. Though nitrogen fertilized trees showed more physiological breakdown in 1928, due to one very bad tree, the difference between plots was not satisfactorily significant.

Investigations have also been made to determine whether potash fertilizers would increase the firmness and the storage quality of fruits (37). All forms of potash were used in combination with nitrate of soda and also in a complete fertilizer with superphosphate. In some cases potash only was used. The work was begun in 1928 and reported upon at the close of 1929.

The apple variety in question was Stayman Winesap and pressure tests were made at the time of picking. No significant differences in firmness of the apples were noted between fruit from plots which received any of the potassium fertilizers in half, single, or double amounts or of nitrate only. Neither did the complete fertilizer treatments influence the initial firmness. Pressure tests recorded during the storage season showed no consistent variations among the various plots. The second year's results confirmed the first. Weinberger suggested after two seasons' work that potash fertilizers could not be considered as affecting the firmness of fruits when used with or without other fertilizers under the soil and climatic conditions of Maryland.

Palmer (33) studied "Jonathan breakdown" in British Columbia and reported annual losses from this cause totalling many thousands of dollars. This disease is not confined to this variety but it is the one most seriously affected. The trouble had been variously attributed to the condition of the trees, the nature of the soil on which they were growing, the amount of thinning practiced, the methods of culture, and the amount of irrigation water applied.

During a 3-year period fruit was harvested from individual trees in various commercial orchards to cover as wide a range of age, type, and vigor of tree, kind of pruning, degree of thinning, method of culture, type of soil, and irrigation practice, as possible. The fruit was wrapped, packed in standard boxes, and placed in a common storage.

It was found that some breakdown occurred in fruit from all the districts but that it was more serious in districts where the soil was relatively heavy. Ample moisture conditions during August and September seemed to be favorable to the development of breakdown, while a deficiency at that season resulted in the production of small, firm textured apples which were seldom affected. Heavy pruning and thinning, light crops, and top-working on a vigorous stock seemed to favor the trouble. Thus, any condition that caused over stimulation of the trees was to be avoided.

The late harvested fruit broke down more frequently than that harvested relatively early, and fruit showing water core also was predisposed to the trouble. Most of the breakdown occurred in large, light colored specimens. However, so long as the apples were picked before they reached an advanced stage of maturity they seldom developed the trouble.

The importance of early picking of Jonathan in order to avoid breakdown was emphasized by Daly (9). He also associated light crops and water core with the susceptibility of the fruit to breakdown and finds no evidence that it is a storage trouble as indicated by Kidd and West (24).

A disease called "soggy breakdown" was described by Plagge and Maney (34); it is particularly destructive to Grimes and Wealthy apples. Jonathan appeared to be immune to the trouble. This type of breakdown did not appear in common storage but was associated with low storage temperatures, especially at 30° F. This would not seem to be the same type as is described by the authors of this paper although certain of the symptoms are similar. It is believed to be the same type reported in England by Kidd and West (24) and in New Zealand by McClelland and Tiller (27).

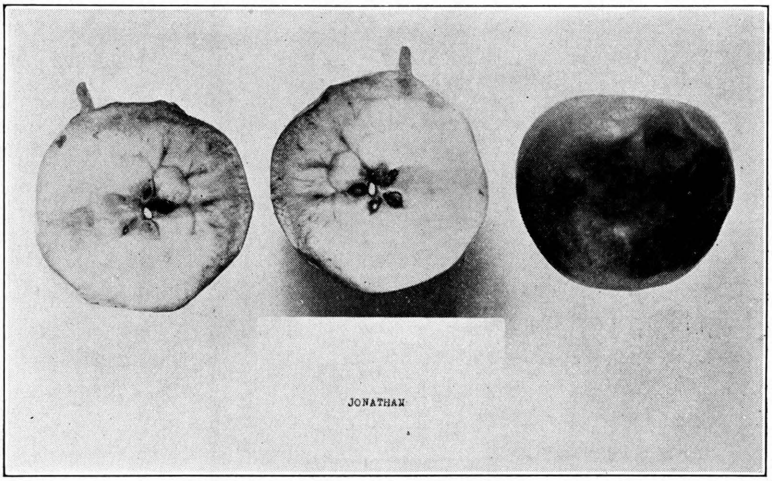

Fig. 1.—Typical physiological breakdown of Jonathan, as described in this paper

Haynes and Archbold (18) stated that the properties which favor keeping have been found to be: low nitrogen and high sucrose, and probably also a large amount of cell wall material, a statement which in substance was made by Archbold (3) also.

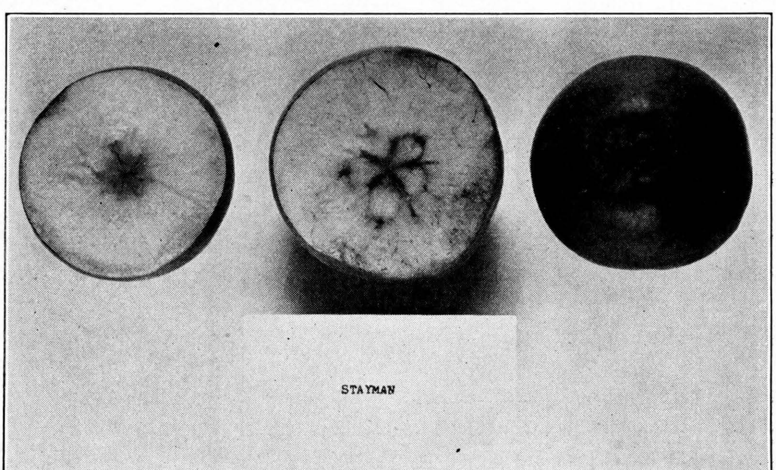

Fig. 2.—Physiological breakdown of Stayman Winesap

INTERNAL BREAKDOWN

The type of breakdown observed in the Experiment Station orchards and elsewhere in the State occurs in both common and cold storage and usually is noticed within a few weeks after picking although it may continue over a considerable period of time.

It may consist of an early mellowing and "mealiness" of the fruit or a definite softening of one side or of the whole cortical region. Frequently, an early stage of the trouble is marked by a browning of the dorsal carpellary bundles and the pith region, followed later by a browning and softening of the flesh or cortex. Jonathan and Stayman Winesap are particularly susceptible under Ohio conditions but other varieties also are involved. (Figs. 1 and 2).

YIELD AND GROWTH IN STAYMAN ORCHARD

As indicated above the younger orchards in this experiment have been tilled and all of the trees are making a satisfactory growth, but the Stayman block has been grown continuously in sod and the untreated trees show less vigor and are notably less productive than those which have been supplied with nitrate fertilizer. The obvious stimulation resulting from the treatments provides suitable material for study in connection with the relation of nitrogen to storage quality of fruit. Table I[1] (see also Fig. 3), which summarizes the growth response for the past 7 years, shows that the average twig growth of the unfertilized trees has been 18.29 cm., that on trees treated with a "normal" quantity of nitrate it has been 28.70 cm., and individual trees treated with approximately 2, 3, 4, and 5 times the normal amount of nitrate have averaged, respectively, 35.18, 32.13, 29.53, and 32.45 cm.

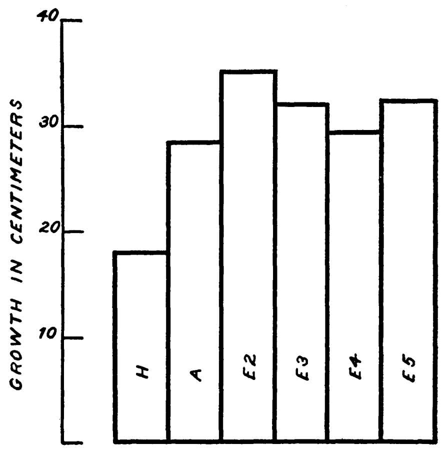

Fig. 3.—Growth in centimeters of Stayman Winesap trees grown in sod. 7-year average. For treatment see Table I.

There has been a still greater response in yield as a result of the treatments, which indicates clearly that under the conditions of

[1]Roman numerals are used for numbering tables in the text; Arabic numerals for those at the back of this bulletin.

this orchard a much heavier annual application of nitrate would be justified than that supplied by the "normal" amount. While color is somewhat reduced it is not seriously so and much is to be gained by a compromise between high color on the one hand and high yields on the other.

In Table II (see also Fig. 4) is a summary of the yield of the trees from 1924 through 1929. As mentioned earlier, this orchard was planted in 1915 and the fertilizer treatments were begun in 1922. The untreated trees have averaged 88.4 pounds per tree; those receiving normal nitrate, 133.3 pounds; those receiving 2, 3, 4, and 5 times the normal have averaged 162.4, 290.5, 189.4, and 286.8 pounds, respectively. It should be stated that the trees receiving the double and quadruple amounts have been pruned back severely because of crowding, which accounts for the reduced yield in those cases.

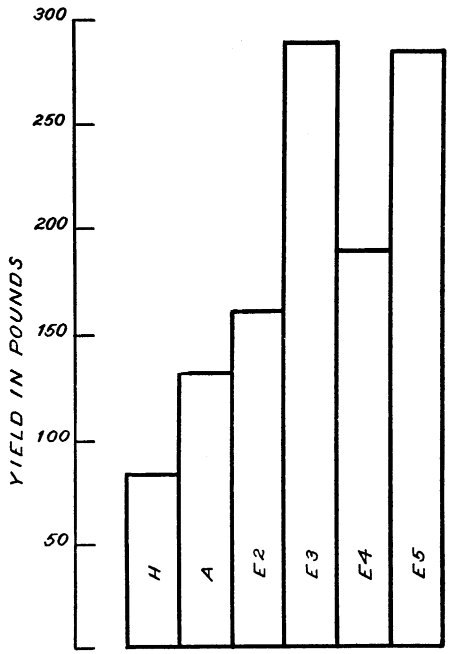

Fig. 4.—Yield in pounds of Stayman Winesap trees grown in sod. 6-year average. For treatment see Table II.

It thus appears evident that the nitrate treatments have affected the growth and yield, and it would be expected that fruit from such trees should be of poor keeping quality if nitrogen was the cause of physiological breakdown. The storage data are discussed in another section of the paper.

CHEMICAL AND PHYSIOLOGICAL STUDIES

METHODS

Sampling and general procedure.—Fifteen apples were selected from each row or tree on which a test was to be made. Care was taken to distribute the sampling evenly throughout the row or tree. The fruits were then brought to the laboratory and the diameter of each apple recorded in centimeters. Notes on the color were also

TABLE I.—Twig Growth. Stayman Block Planted in 1915

Average 20 twigs per tree

Tree	1924 cm.	1925 cm.	1926 cm.	1927 cm.	1928 cm.	1929 cm.	1930 cm.	7-yr. average cm.
Unfertilized plot—H								
1	34.41	20.16	19.00	13.00	7.68	6.98	6.22	15.35
2	37.00	18.83	17.00	10.32	16.82	12.12	17.72	18.54
3	31.25	18.16	13.00	15.40	18.15	14.32	7.65	16.84
4	27.50	17.66	18.00	24.72	23.22	15.90	10.50	19.64
5	38.33	20.50	26.00	26.60	13.90	14.25	8.42	21.10
Average	....	....	....	....	....	....	....	18.29
Normal nitrate applications (¼ lb. for each year of tree's age)—A								
1	30.57	28.85	19.00	31.68	33.98	26.95	21.60	27.52
2	27.14	34.14	20.00	34.12	33.52	26.78	15.32	27.29
3	24.24	36.78	25.71	41.95	35.00	30.25	20.70	30.66
4	26.35	37.35	28.00	26.05	26.48	33.40	18.50	28.02
5	34.43	28.85	29.14	34.15	30.90	33.18	19.45	30.01
Average	....	....	....	....	....	....	....	28.70
Excess applications of nitrate over normal								
Double normal E2.	58.00	44.00	25.00	28.32	31.42	33.35	26.20	35.18
3 times normal E3.	42.21	30.34	29.00	30.05	33.98	31.45	27.90	32.13
4 times normal E4.	34.57	29.64	22.00	25.62	31.55	42.22	21.12	29.53
5 times normal E5.	43.00	29.28	28.00	33.52	31.50	34.88	27.00	32.45

TABLE II.—Yield. Stayman Block

Tree	1924 lb.	1925 lb.	1926 lb.	1927 lb.	1928 lb.	1929 lb.	Average lb.
Unfertilized plot—H							
1	11.1	15.0	140.0	122.0	196.5	23.3	84.6
2	.8	3.0	152.0	166.0	131.0	27.3	82.8
3	0	0	52.0	161.0	82.5	22.5	53.0
4	0	5.0	151.0	244.0	160.5	41.3	98.6
5	7.2	.5	110.0	171.0	415.0	34.3	123.0
Average	....	....	....	....	....	....	88.4
Normal nitrate applications—A							
1	78.4	121.2	410.0	52.0	245.0	38.6	157.53
2	2.5	8.5	117.0	14.0	39.0	1.0	30.1
3	8.7	9.0	222.0	87.0	61.5	21.0	68.2
4	6.4	62.0	405.0	104.0	188.0	110.7	146.0
5	1.3	119.2	524.0	248.0	303.0	392.5	264.6
Average	....	....	....	....	....	....	133.3
Excess applications of nitrate over normal							
Twice normal E2	51.2	109.0	391.0	194.0	146.5	83.1	162.4
3 times normal E3	62.6	195.5	619.0	432.0	200.0	233.8	290.5
4 times normal E4	26.7	154.0	433.0	304.0	41.0	178.0	189.4
5 times normal E5	59.7	168.8	618.0	419.0	182.5	273.2	286.8

made, the sample weighed, and the result recorded in grams. Next, the fruits were placed in the chamber of a respiration apparatus, which was set up in an insulated room held at 70° F., and the rate of evolution of carbon dioxide determined. Following this, the apples were removed from the apparatus, cut into quarters (one lot at a time), and the cores removed. A thin slice was removed from one quarter of each apple in such a manner as to include the skin until 10 grams were obtained. This was done as rapidly as possible and the weight obtained to an accuracy of 0.01 gram on a small torsion balance. This sample was immediately mixed with 2 grams of $CaCO_3$ (precipitated chalk) and ground thoroughly to a fine paste. It was then transferred to a small bottle with 20 cc. of distilled water, stoppered, and allowed to stand overnight when the catalase activity was determined. The method of Heinicke (21), as modified by Knott (26), was used.

Returning to the remainder of the sample, thin slices were cut from the quartered apples until 50 grams of tissue were obtained. This was weighed into a pyrex glass evaporating dish in the bottom of which a filter paper was placed to prevent the juice from coming in contact with the dish. The dish was placed in a vacuum oven and dried at 100° C. for 24 hours for the moisture determination. At this temperature, however, it was found that considerable carmelization took place, and during the second season the standard procedure of 80° C. for 48 hours at a vacuum of about 29 inches was adopted. With this procedure there was practically no carmelization.

The dried sample from the moisture determination, together with the filter paper, was placed in a Kjeldahl flask for the nitrogen determinations.

Fifteen other quarters of the apples, one from each apple, were reduced to a pulp in a small Nixtamal mill, mixed well, and samples taken for the following determinations: 1. A 50-gram sample was weighed out and allowed to freeze over night in a refrigerated room at about 14° F. for the estimation of soluble pectin. 2. An unweighed sample of about 100 grams was frozen, kept for determinations of total acids, specific gravity, hydrogen-ion concentration, buffer action, and total solids of the juice. 3. A 100-gram sample was weighed out for carbohydrate analysis and determination of alcohol soluble and insoluble nitrogen fractions. This was preserved in 80% alcohol.

Respiration apparatus.—The respiration apparatus used in this work was very similar, with some modifications, to that used by the junior author (23) in a study of potato respiration. A diagram of the apparatus is shown in Figure 5. The parts may be briefly described as follows: *A* is a tube filled with 4-mesh soda lime, the purpose of which is to remove CO_2 from the air which is drawn into the apparatus; *B* is a trap to prevent the $Ba(OH)_2$ solution from *C* entering the soda lime tube in case of back pressure; *C* is a bubble tube about half full of clear $Ba(OH)_2$ solution, the purpose of which is to test the efficiency of the soda lime in removing CO_2 from the entering air and to serve as a test for leaks in the apparatus beyond *C*. It also serves to humidify the air to some extent before it enters the respiration chamber; *D* is the respiration chamber in which the fruit was placed. It consists of a large desiccator with a well ground, tubulated lid. The tube from *C* which carries the air into this chamber just passes through the stopper; while to the one which carries the air out a rubber tube which reaches to the bottom is connected; *E* is the absorption unit consisting of a one-liter filter flask with a side tubulation. Into this flask is fitted, by means of a rubber stopper, a glass tube, *e*, 22 mm. x 2.5 ft. In the lower end of this tube which is drawn to a small diameter is placed a column of glass beads about 3 inches in height. The top of *e* is fitted with a rubber stopper carrying a right angle bend. This absorption unit is connected with the outlet from the respiration chamber by means of a short piece of rubber tubing on the side tubulation on the filter flask. The solution for absorbing the CO_2 produced by the fruit during respiration is placed in this flask and the tube *e* is adjusted by sliding it up or down through the stopper so that bubbles of air-CO_2 mixture enter the lower end of the tube when the height of the absorbing solution is from ½ to ⅔ that of *e*. The glass beads serve to break up the air into smaller bubbles so as to allow better absorption of the CO_2; *F* is a trap identical with *B* to prevent $Ba(OH)_2$ solution from entering *e* in case of accidental back pressure; *G* is a bubble tube containing clear $Ba(OH)_2$ solution to test the efficiency of the absorption unit *E*, in absorbing the CO_2; *H* is a gas needle valve for regulating the flow of air through the apparatus. These valves have proved superior to screw pinchcocks for this purpose since they assure a greater constancy of air flow when once set.

Six sets of the apparatus described thus far were assembled in the constant temperature room and each was connected to a main "suction line". This suction line was connected to a large 5-gallon bottle, *I*, which serves the purpose of giving a more constant suction on the line in case of variable water pressure. From *I*, connection was made under mercury to a bottle, *K*, which acts as a trap to prevent water from the aspirator pump entering the apparatus in case of a temporary reduction in the water pressure. Suction is furnished by a large water aspirator pump. Between *I* and *K* was inserted a mercury pressure regulator, *J*, by means of a "T" tube. This regulator can be adjusted for the pressure desired by raising or lowering the bulb tube in the mercury in the bottle. If the pressure increases above this point air will leak in through the bottom of the bulb tube and tend to reduce it.

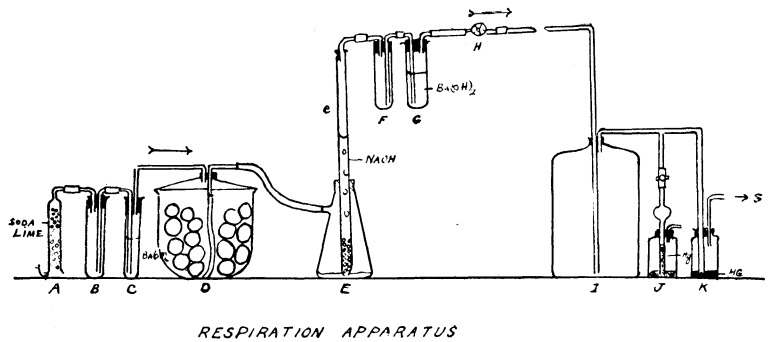

Fig. 5.—Respiration apparatus used in studying the respiratory rate of apple fruits. Description is given in the text

No claim for originality is made in describing this apparatus although certain modifications have been developed by the junior author at various laboratories. It is essentially a modification of the apparatus described by Gore (13) and by Magness and Burroughs (28). The apparatus is described in detail since it is thought to be a convenient one to use where one wishes to determine the rate of respiration by a determination of the CO_2 produced in a continuous flow system.[2]

[2]In this connection several improvements have been used by the junior author elsewhere. One of these was the introduction of a flowmeter of the Venturi type between the bottle tube *C* and the respiration chamber *D* to maintain a known and constant rate of flow through the apparatus. Harding, Maney, and Plagge (16) have indicated the use of a flowmeter in a respiration apparatus described by them but do not give the details of its construction. A simple type of flowmeter which may easily be constructed in any laboratory has been used by the junior author in the laboratory of the United Fruit Company at Boston, Massachusetts, and in the Laboratory of Plant Physiology at Cornell University. This consisted (Fig. 5) of a glass "U" tube about 5 mm. in diameter connected by two "T's" to a horizontal glass tube at the top. In the center of the horizontal tube was sealed a piece of capillary tubing, the bore of which was adjusted for the rate of flow desired. The "U" tube was filled about half full with a paraffin oil of low viscosity. The flowmeter after being mounted on a wooden standard was then calibrated by means of an aspirator bottle and a stopwatch. The calibrations are marked on a paper fastened back of the U tube.

Another modification which is desirable when the respiration is to be studied over long periods is a direct connection from the respiration chamber, *D*, to the needle valve, *H*. In this way the absorption unit may be removed without interrupting the flow through *D*. A manometer (Fig. 6) may also be inserted in the stopper in *D* to determine the extent and constancy of the vacuum in *D* although in an apparatus of this type the negative pressure amounts to only a few millimeters of mercury. When the respiration chamber temperature is controlled by immersion in a constant temperature water bath, the air entering *D* should first pass through a coil of copper tubing about 10 feet long immersed in the water bath. (See Spoehr and McGee (35), p. 35).

The absorption tower, *e* (as described above), is very efficient in absorbing CO_2, when used with concentrations of NaOH from N/1 to N/5, and it is much simpler in construction than the Riset tube (See Gore (13), p. 8) with its various proposed modifications. With rates of flow as high as 20 liters per hour and with high CO_2 concentrations (from ripening bananas), no turbidity will be observed in the bubble tube, *G*.

Respiration procedure.—Each lot of 15 apples was placed in the constant temperature room and allowed to come to the temperature of the room (70° F.). One hundred cc. of N/5 NaOH were then placed in the absorption unit, *E*, and the tube, *e*, fitted in. The apples were placed in *D* and the lid replaced so that the rubber tube reached to the bottom. The time of start was recorded when the apples were sealed in the respiration chamber. With all connections made and the suction already turned on at *S*, the needle valve, *H*, was adjusted to give a fairly rapid rate of flow. The tube, *e*, was moved up or down through the rubber stopper so that the NaOH solution stood at the proper height in *e*. At the end of a definite time, 5 or 6 hours, the run was stopped by removing the stopper at the top of *e*.

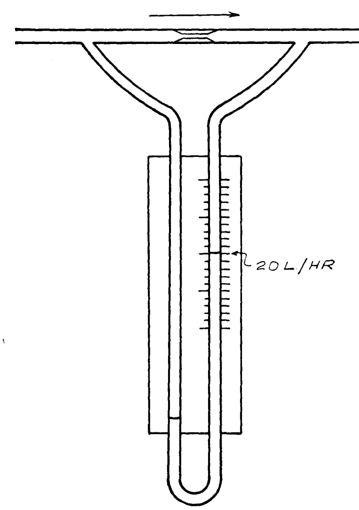

Fig. 6.—Flowmeter which may be used in regulating the flow of air through respiration apparatus.

The absorption unit was then disconnected, stoppered, and taken to the laboratory for the titration. The tube, *e*, was raised through the stopper so that the lower end of it was well above the surface of the liquid in the flask and the walls of the tube and the glass beads rinsed with distilled water, which was allowed to run into the flask. The absorption tube was removed and the flask stoppered with a solid rubber stopper. The side tubulation was closed with a piece of rubber tubing carrying a glass plug. The flask was set aside until the titration was made.

The titration was carried out as follows: To the solution in the filter flask enough $BaCl_2$ solution was added to precipitate all the carbonate as $BaCO_3$ and leave an excess of the $BaCl_2$ (in these experiments 10 cc. of a solution containing 200 gm. $BaCl_2 \cdot 2H_2O$ per liter were sufficient). The excess of alkali was then titrated with N/2 HCl in the presence of phenolphthalein. The precipitate of $BaCO_3$ was left in the flask during the titration.[3] A blank determination was made on 100 cc. of the original NaOH solution plus the same amount of $BaCl_2$ used above. The difference between the blank and the respiration determination will be equivalent to the CO_2 evolved in terms of cubic centimeters of the standard N/2 HCl. This titration is essentially the one used by Winkler for the determination of NaOH in the presence of Na_2CO_3 (36).

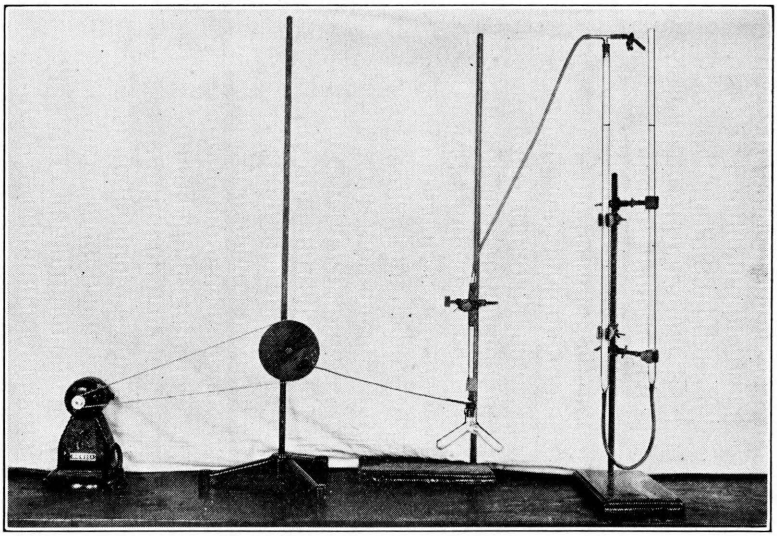

Fig. 7.—Apparatus used in the determination of catalase activity of apple fruits

Catalase.—The preparation of the sample for the catalase determination was described above under "Sampling and general procedure", and a diagram of the apparatus is shown in Figure 7. The procedure was as follows: Adjust the temperature of the water bath to 25° C. ± 0.2. Thoroughly shake the sample and quickly draw up 2 cc. into a pipette with a large opening at the lower end. Place this 2 cc. sample in one arm of the reaction tube. Allow the sample to stand in the reaction tube for 8 minutes and then add 2 cc. of fresh H_2O_2 (12 volume Dioxygen), neutralized with $CaCO_3$, in the other arm. Connect the tube to the apparatus

[3]The CO_2 produced in milligrams per kilogram of fruit per hour was obtained from the following formula:

$$\frac{\text{Blank—titration} \times CO_2 \text{ factor for acid}}{\text{Weight of fruit in kilos} \times \text{hours}} = CO_2 \text{ M-K-H}$$

with the screw pinchcock open at the top of the burette. Adjust the level of the water to the zero mark and allow the reaction tube to come to the temperature of the water bath. Close the pinchcock and start the shaking motor and stop watch. Take readings on the burette at the end of ½, 1, 2, 3, 4, 5, 6, and 7 minutes.

Moisture.—The details of this determination are given above under "Sampling and general procedure." A detailed experiment on one set of samples showed that practically a constant weight was obtained for the standard conditions finally adopted; namely, 80° C. in a vacuum for 48 hours.

Nitrogen.—For this purpose the modified Gunning method to include the nitrogen of nitrate was adopted (32, p. 8). Although it is claimed by Archbold (3) that there is no nitrate or other form of nitrogen than protein in apple fruits, this modification was used as a precautionary measure since some of the trees from which the samples were taken had received rather high applications of sodium nitrate.

Total acidity and hydrogen-ion concentration.—At first the total acid and hydrogen-ion concentration were determined on separate samples of the pulp, the former on the extract used in the pectin determination and the latter on the juice pressed from a sample of the pulp which had been frozen. Finally, however, since the accuracy of this method for total acid seemed doubtful, both the pH and total acid were determined electrometrically using the quinhydrone electrode. A sample of juice from pulp which had been frozen was used. For this purpose an unweighed sample (about 100 grams) of the pulp was frozen over night and then, after thawing, the juice was pressed out in a Carver hydraulic press at 5000 pounds pressure per square inch. This juice was centrifuged to throw down any starch which may have come through the press and the specific gravity of the juice was determined at 25° C. by weighing 10 cc. of the juice in a 50 cc. tared-beaker. Quinhydrone was then added to this 10 cc. sample of juice and the pH determined electrometrically. Increasing amounts of N/10 NaOH were added to the sample and the pH was determined after each addition. From this data the total acid as malic in the 10 cc. of juice was determined graphically from a titration curve. The percentage of acid as malic in the original pulp was obtained from the following formula:

$$\frac{a \times b \times c}{d} = \% \text{ malic acid}$$

a = cc. N/10 NaOH per 10 cc. juice
b = malic acid factor for the N/10 NaOH
c = percentage of juice in the pulp
d = weight of 10 cc. of juice

The value c is obtained as follows: The juice in the pulp is equal to the water in the pulp plus the solids in the juice. Let c = the juice in the pulp (gms. per 100 gms.) Then

c = gms. water in pulp + solids in juice[4]

or c = gms. water in pulp + (gms. solids per gm. juice) × c

Example: A sample of apple tissue has 87% H_2O and the specific gravity of the juice is 1.028. The solids in the juice = 7% (See 32, p. 66)

$c = 87 + .07\ c$

c = 93.55 gms. of juice per 100 gms. pulp

Now if 10.25 gms. juice show a titration of 14.13 cc. N/10 NaOH

$$\text{then } \frac{14.14 \times .0067 \times 93.55}{10.25} = 0.864\% \text{ malic acid}$$

It is suggested that this procedure may be used in the calculation of the percentage of other constituents in apple pulp from an analysis of the juice. The method of determining the total solids from the specific gravity of the juice was checked on two samples of juice by evaporation in a vacuum at 80° C. for 48 hours with the following results:

	E 2	E 4
Per cent solids in juice by evaporation	7.16	7.36
Per cent solids in juice obtained from specific gravity	7.30	7.30

Since a fairly large error in the determination of the percentage of solids in the juice will cause only a small error in the calculated per cent of malic acid, calculation in the above manner from the specific gravity is deemed sufficiently accurate. As for the method as a whole, it should be checked by alcohol extraction methods. This is essentially the same procedure as used by Mason and Maskell (30) in calculating the percentage of sugar in the tissue of the cotton plant from an analysis of the sap. Haynes and Archbold (17 and 18) have published a similar method in which, however, it is necessary to know the weight of the residue from the alcoholic extraction. Their formula is:

$$x = \frac{C\ (100-r)}{100\ \sigma}$$

in which C is the concentration of any substance in the juice; r, the residue from the alcoholic extraction; σ, the specific gravity of the juice; and x, the concentration of C in the pulp.

[4]This is on the basis that the juice left in the pulp after pressing has the same composition as the juice pressed out (See 17 and 18).

The electrometric determinations of hydrogen-ion concentration were checked in a number of cases colorimetrically. The juice was placed in a collodion sac and dialyzed against an equal volume of distilled water for about 24 hours and then the colorimetric determination was made on the clear but greenish-colored dialysate. Clark's phthalate-HCl buffers were used for this purpose, the tubes being arranged in a Gillespie comparator block so as to compensate for the color of the solution. Agreement with the electrometric determinations was obtained within the limits of the colorimetric method.

Soluble pectin.—The 50-gram sample of the pulp which had been frozen (see "Sampling and general procedure") was used for this determination. In general, the method of Carré and Haynes (6, 7, 8) was used. The pulp was thawed out at room temperature and then pressed out in cloth in a hand press. The dry cake was then ground in a mortar with 40 cc. of distilled water and again pressed as before. The washing was repeated five times and each time the washings were added to the original juice. The mixture was centrifuged to remove starch (in the case of green apples) and other suspended matter which came through the press cloth. The extract was poured from the residue in the centrifuge tubes and the residue washed twice with 40 cc. water, the washing in this case being added to the rest of the extract. The extract was boiled for 5 minutes and allowed to cool.

The next step in the procedure calls for a filtration of extract, but filtration was practically impossible, especially in the case of green apples. Many procedures were tried to facilitate the filtration, and it was finally found that a preliminary treatment of the extract with decolorizing carbon gave good results. This was done as follows: Five grams of decolorizing carbon (Baker and Adamson) were added to the extract and the mixture heated to 80° C., with constant stirring. It was then immediately filtered into a 500 cc. volumetric flask through an S. & S. No. 589, white ribbon 150-mm. filter and the residue and carbon washed with hot water until the volume was about 500 cc. The precipitation and weighing of the pectin, as calcium pectate, were then carried out exactly according to Carré and Haynes (7).

Since the question may come up as to the effect of the decolorizing carbon in removing some of the pectin from solution by adsorption, this point was tested out. First, a sample of apple juice was obtained and the starch removed from it by centrifuging. It was then divided into two portions, one of which was cleared with carbon as described above, while the other portion was handled as follows: The extract was heated to boiling, boiled 5 minutes, and allowed to cool. It was then reheated to 80° C. and filtered through a folded S. & S. No. 589 filter. The filtration was slow but took place over night. Clear filtrations were obtained in both cases, but the one to which no carbon had been added showed a brownish color. The pectin was then determined, and the results were as follows:

CRUCIBLE	SAMPLE	WT. CA PECTATE
1	carbon	0.0062 gm.
6	no carbon	0.0063 gm.

This indicates that the carbon clearing did not remove any of the pectin from solution. After drying in the crucibles the sample with no carbon was black in color, while the cleared one showed the usual grayish color of calcium pectate.

A further experiment was performed on a sample of commercial pectin (Certo). Twenty-five cc. of this preparation were diluted to 250 cc., and 20 cc. of the diluted sample were placed in each of four beakers. The first two were treated with carbon as described above, and the second two were treated exactly the same but without the addition of carbon. The pectin was determined with the following result:

CRUCIBLE	SAMPLE	CA PECTATE
		gm.
16	#1 carbon	0.0069
12	#2 carbon	0.0060
13	#3 no carbon	0.0059
2	#4 no carbon	0.0060

The treatment with carbon then, while facilitating the filtration, does not cause an error in the method.

RESULTS

The data for the various analyses carried out on each sample are presented in separate tables at the end of this bulletin. Summarized data from these tables will be found in the text.

Nitrogen.—The data for the nitrogen determinations on the Stayman block (mature trees in sod) are summarized in Table III.

These results show clearly that nitrate applications result under these conditions in a marked increase in the nitrogen content of the fruit over the control, whether this is expressed as percentage of the fresh weight or on the basis of grams of nitrogen per 15

TABLE III.—Mature Stayman Trees in Sod—Nitrogen

Row and tree	Treatment—Lb. $NaNO_3$ per tree	7-31-28		9-6-28		7-9-29		7-30-29		8-12-29		9-5-29	
		% N	Gm. N per 15 fruits	% N	Gm. N per 15 fruits	% N	Gm. N per 15 fruits	% N	Gm. N per 15 fruits	% N	Gm. N per 15 fruits	% N	Gm. N per 15 fruits
H..........	None	0.0339	0.2231	0.0192	0.2542	0.0350	0.1827	0.0311	0.2747	0.0275	0.3070	0.0217	0.3016
A..........	1¾	.0308	.1979	.0234	.3673	.0439	.2546	.0338	.3434	.0309	.3706	.0232	.4566
E 2........	6	.0444	.3422	.0297	.5043	.0470	.3083	.0449	.4881	.0469	.5920	.0323	.6105
E 3........	8	.0505	.3829	.0297	.5159	.0764	.4309	.0481	.4868	.0581	.6863	.0363	.7078
E 4........	12	.0428	.3931	.0295	.5364	.0593	.3920	.0440	.5162	.0480	.6896	.0412	.8158
E 5........	14	.0414	.3457	.0260	.5182	.0659	.3941	.0418	.4677	.0483	.6892	.0363	.6844

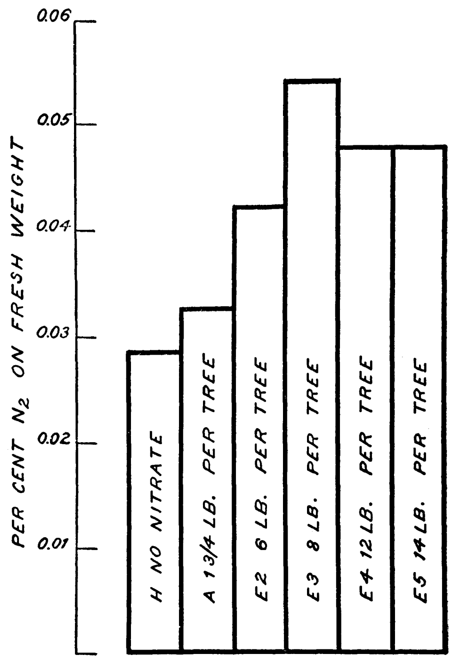

Fig. 8.—Percentage of total nitrogen in fruit from trees receiving different amounts of sodium nitrate. Average values for 1929. Stayman Block.

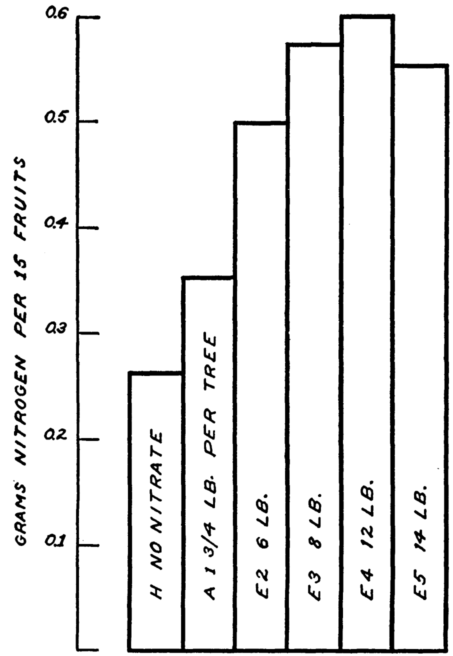

Fig. 9.—Grams of nitrogen per 15 fruits. Average values for 1929. Stayman Block

fruits. In many cases this increase is well over 100%. Further, the amount of nitrogen in the fruit rose with increasing amounts of nitrate up to 8 pounds per tree. A still greater increase in the amount of nitrate applied did not result in a larger increase in the nitrogen content of the fruit but, in some cases, resulted in a smaller increase. While the explanation for this is not clear it is suggested that the large applications of this salt have injured the upper roots to some extent. It will be seen from Table III that in only one instance did fruit from trees which had been fertilized with sodium nitrate show a lower nitrogen content than the control. This was in the samples taken July 31, 1928, in which case the trees receiving a "normal" amount of nitrate showed a slightly smaller amount of nitrogen in the fruit than the control. Other samples from this row taken the same year, however, showed the reverse. The average results for 1929 are shown graphically in Figures 10 and 11.

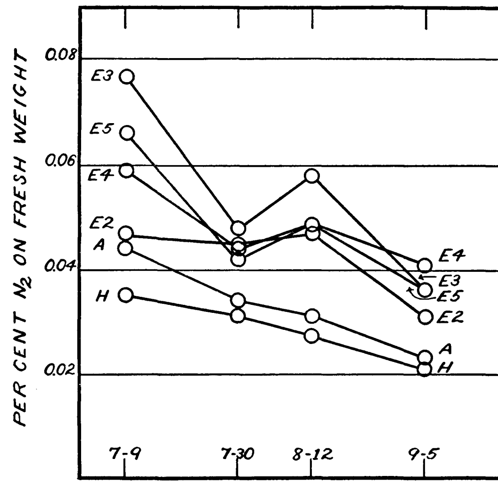

Fig. 10.—Changes in the percentage of nitrogen during the 1929 season. Stayman Block

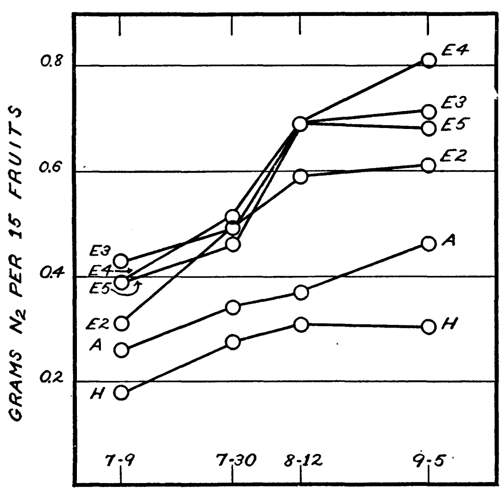

Fig. 11.—Changes in the total amount of nitrogen in 15 fruits during the 1929 season. Stayman Block

The data for the nitrogen determinations on Wealthy apples from the East orchard (young trees in cultivation) will be found in Tables 15 and 16. The results for one set of samples taken on August 20, 1928, are shown graphically in Figures 12 and 13. All the rows

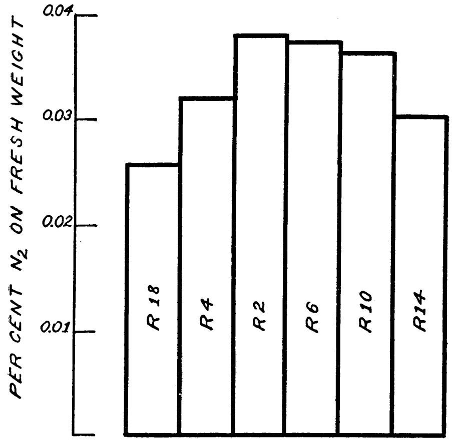

Fig. 12.—Percentage of nitrogen in fruit. Wealthy, East Orchard, 8-20-28, R 18, no fertilizer; R 4, 1¾ lb. $NaNO_3$; R 2, 5¼ lb. $NaNO_3$ per tree; R 6, complete fertilizer; R 10, complete fertilizer minus K; R. 14, complete fertilizer minus P.

receiving nitrate applications show both a higher percentage and a higher total amount per 15 fruits than the control which received no nitrogen. There appear to be no significant differences in the fruit from the treated rows. The results are similar whether the nitrate is used alone or as a constituent of a complete fertilizer or in combination with phosphorus or potassium.

While the results in the case of the Stayman block seem to show without doubt that nitrate applications result in an increase in the amount of nitrogen in the fruit, it was decided to examine this point statistically as far as possible with the material available. For this purpose, fruit samples were taken from each of five Wealthy trees from the control row (Row 18) in the East orchard which had received no fertilizer and also from five trees in the row (Row 2) which had received applications of nitrate at the rate of 5¼ pounds per tree. With one exception, fruit from trees in Row 18 all show a lower percentage of nitrogen on the fresh weight than the lowest percentage in fruit from Row 2. The probable error of the difference between the two rows equals

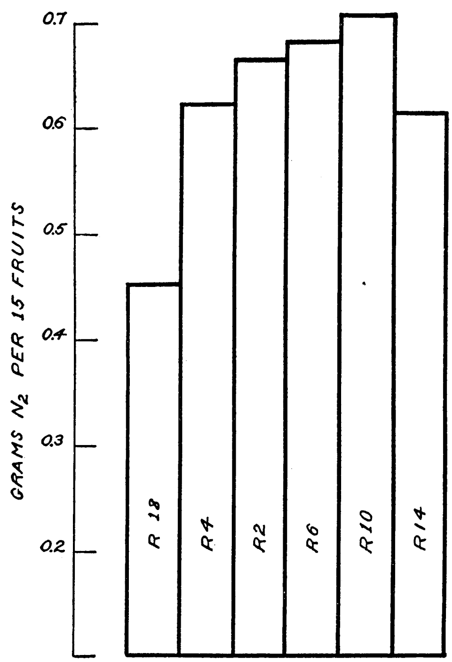

Fig. 13.—Grams of nitrogen per 15 fruits. Wealthy, East Orchard, 8-20-28. For treatments see Figure 12.

± 0.00306, and the difference over this value $\left(\frac{d}{PE_d}\right)$ equals 3.13, which indicates a significant increase of the treated over the control. When calculated on the basis of the total nitrogen in fifteen fruits, $PE_d = \pm 0.1032$ and $\frac{d}{PE_d} = 3.49$. The results are shown in Table 16 and graphically in Figures 14 and 15. The increase of the treated over the control in the first case is 33.7% and in the second 48.7%.

The nitrogen analyses for Stayman trees in the East orchard also show that nitrate applications result in an increased percentage, as well as total amount per fruit, as compared with the control. The data for these trees are recorded in Tables 17, 18, and 19. The average results for the 1929 season are shown graphically in Figures 16 and 17. Here again it will be seen that the fruit from every row that received sodium nitrate showed a higher amount of nitrogen than did that from the control.

Two samples from Stayman trees were also taken from an orchard in sod, which is used for pruning and fertilizer tests. One sample came from a row which had received no fertilizer, and the other came from a row receiving 2⅛ pounds of nitrate in April and 2⅛ pounds in June per tree. The result is given in Table 20. Although these apples show the lowest percentage of nitrogen of any analyzed in the course of this investigation, the percentage in the treated row is greater than that of the control by about 20%, or on the basis of total grams of nitrogen in 15 apples, about 27%.

The nitrogen analyses of fruit from Jonathan trees in the West orchard do not show such striking increases as those found in the above data. However, with one exception, in which the nitrate was applied in August (Row 7, in 1928), the treated rows show a greater percentage and a greater total amount of nitrogen in the fruit. Three sets of samples were taken for each of the two seasons, 1928 and 1929. The results are shown in Tables 9 to 14 and in Figures 18 to 21. Apparently, the summer application is not as effective, since, in this case, the nitrogen in the fruit was about the same as in the control, while the fall application (as shown in the 1929 data) appears to give better results. The fact that the increases in the treated rows are not as great may possibly be explained as due to the development of nitrates in the soil because of cultivation. The effect of the addition of sodium nitrate would

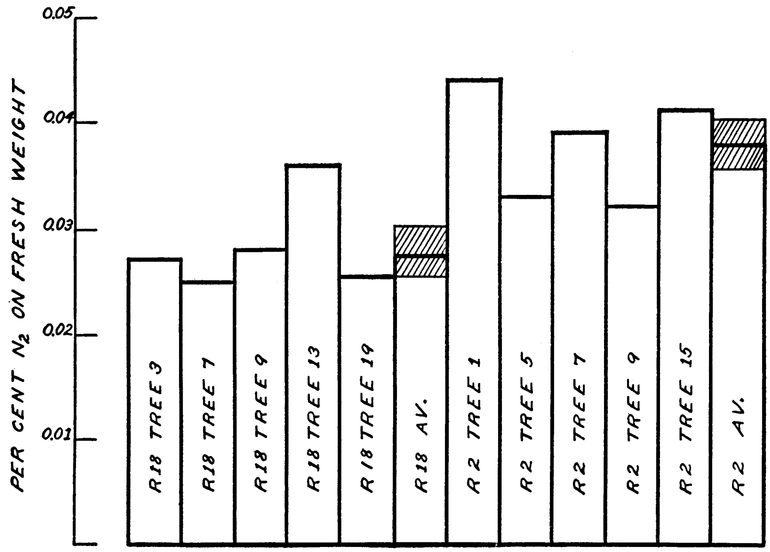

Fig. 14.—Percentage of nitrogen in fruit from unfertilized trees (R 18) and from trees receiving 5¼ lb. $NaNO_3$ (R 2) per tree. Wealthy, East Orchard, 8-15-29. The shaded areas represent the probable error of the mean for each row.

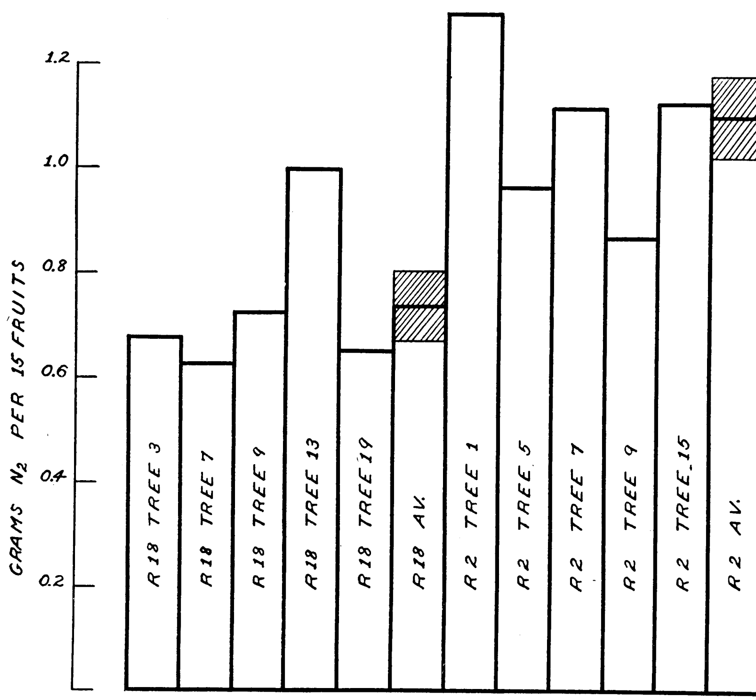

Fig. 15.—Grams of nitrogen per 15 fruits for the samples shown in Figure 14

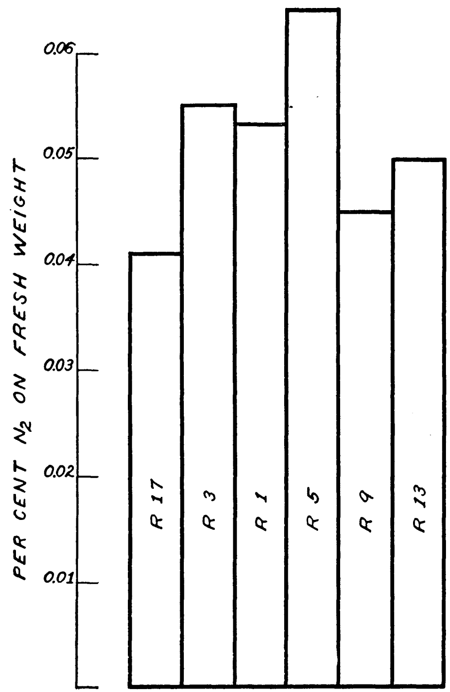

Fig. 16.—Per cent N_2. Stayman, East Orchard. Av. values, 1929. R 17, no fertilizer; R 3, 1¾ lb. $NaNO_3$; R 1, 5¼ lb. $NaNO_3$ per tree; R 5, complete fertilizer; R 9, complete fertilizer minus K; R 13, complete fertilizer minus P.

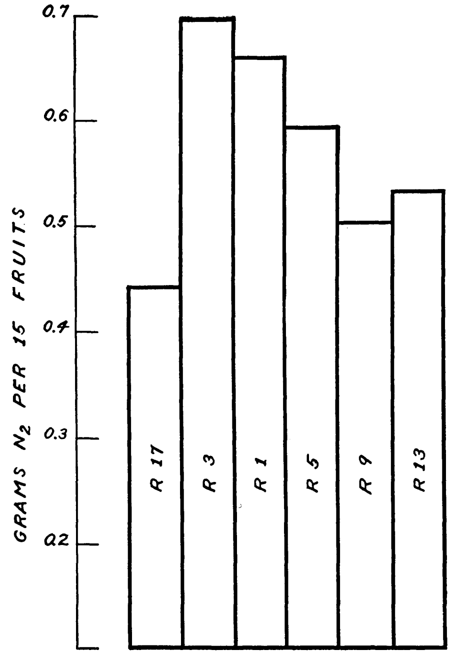

Fig. 17.—Grams of nitrogen per 15 fruits. Stayman, East Orchard. Average values for 1929. For treatments see Figure 16.

then be offset to some extent because of this. Another contributing factor to this result may be that these trees had not received the applications for as long a time. As will be seen later, this smaller accumulation of nitrogen is reflected in the results for catalase and other determinations.

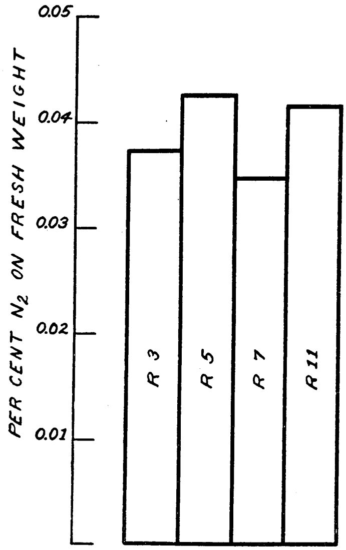

Fig. 18.—Percentage of nitrogen in fruit. Jonathan, West Orchard. Average values for 1928. R 3, no fertilizer; R 5, 1¾ lb. $NaNO_3$ April; R 7, 1¾ lb. $NaNO_3$ August; R 11, ⅞ lb. $NaNO_3$ April and ⅞ lb. August.

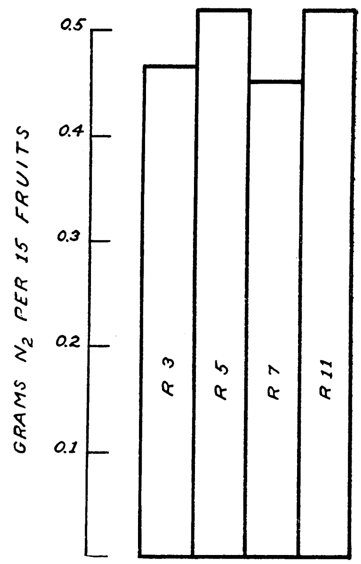

Fig. 19.—Grams of nitrogen per 15 fruits. Jonathan, West Orchard. Average values for 1928. For treatments see Figure 18.

The data for McIntosh trees in the West orchard show a result very similar to that obtained for Jonathan trees. Two sets of samples were taken during the 1929 season. The nitrogen analyses for these samples will be found in Tables 21 and 22 and Figures 22 and 23. The treated rows all show a greater amount of nitrogen in the fruit, although the increases over the control are not very striking.

In summarizing the results of the nitrogen analyses, it is clear that, for the different varieties and for the three different orchards in which the studies were made, applications of sodium nitrate bring about an increase in the nitrogen content of the fruit whether the calculation is made as percentage in the pulp or as the total amount per given number of fruits. The results with trees in sod are very striking and, while with trees in cultivation the increases are not so marked, there is a definite trend towards increases with nitrate applications. This is in contradiction to the suggestion of Haynes and Archbold (18) that the nitrogen supply increases the setting and size of fruit (as is well known) but not the percentage of nitrogen in the fruit. Archbold (3) further states that the

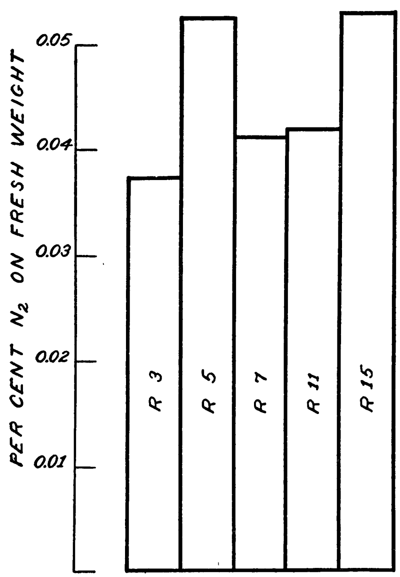

Fig. 20.—Percentage of nitrogen in fruit. Jonathan, West Orchard. Average values for 1929. R 3, no fertilizer; R 5, 1¾ lb. $NaNO_3$ April; R 7, 1¾ lb. $NaNO_3$ August; R 11, ⅞ lb. $NaNO_3$ April and ⅞ lb. August; R 15, 1¾ lb. $NaNO_3$ September.

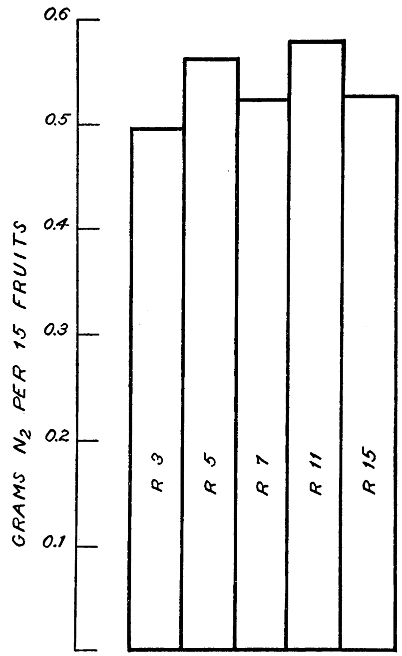

Fig. 21.—Grams of nitrogen per 15 fruits, Jonathan, West Orchard. Average values for 1929. For treatments see Figure 20.

nitrogen content of the apple is not much affected by variation in the supply to the spur, such variations altering yield and size only. However, in our experiments, while obtaining the usual increases in tree growth, yield, and size of fruit, we have also shown that the addition of nitrate does increase the percentage of this element in the fruit in spite of the larger size of apples from such fertilized trees.

Catalase.—A study of the catalase reaction of the fruits was undertaken to determine if the nitrate fertilization would bring

TABLE IV.—Mature Stayman Trees in Sod—Catalase

Row and tree	Treatment—Lb. $NaNO_3$ per tree	Cubic centimeters of O_2 in 5 minutes						
		7-31-28	9-6-28	7-9-29	7-30-29	8-12-29	9-5-29	Averages, 1929
H	None	1.64	2.90	1.39	1.51	1.78	1.41	1.52
A	1¾	2.56	4.75	2.04	2.46	3.79	2.29	2.64
E2	6	3.20	5.50	2.66	4.75	5.23	3.15	3.948
E3	8	3.47	5.40	3.78	3.90	4.54	3.60	3.955
E4	12	2.15	4.64	3.23	4.18	4.30	3.28	3.75
E5	14	2.34	3.60	3.21	2.98	3.67	2.45	3.08

about an increase in this enzyme similar to that which has been observed in the case of the twigs and foliage of nitrate fertilized trees. (See Heinicke, 21 & 22). Positive results would thus tend to substantiate those obtained in the nitrogen analyses. This proved to be the case. In the Stayman block the catalase activity was found to be closely correlated with the nitrate treatment and with the percentage of nitrogen in the fruit. Table IV summarizes the results of catalase determinations from this orchard.

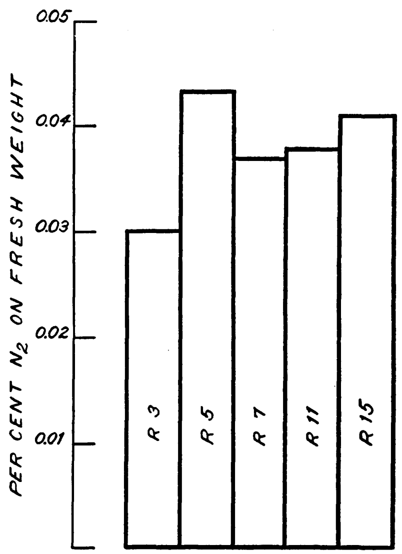

Fig. 22.—Percentage of nitrogen in fruit, McIntosh, West Orchard. Average values for 1929. For treatments see Figure 20.

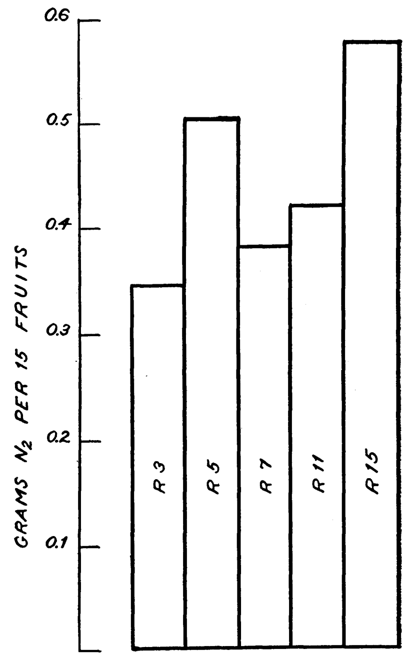

Fig. 23.—Grams of nitrogen per 15 fruits, McIntosh, West Orchard. Average values for 1929. For treatments see Figure 20.

As was stated under methods, the oxygen evolved was recorded at a number of intervals of time but in this article, to save space, only the average values obtained for 5 minutes are recorded. It should be said that close agreement was found between duplicate determinations made on each catalase preparation, usually within a few hundredths of a cubic centimeter. Below are recorded the results of typical determinations on one sample to indicate the order of accuracy.

Time in minutes ..	½	1	2	3	4	5	6	7
cc. O_2 I	0.80	1.32	2.10	2.69	3.10	3.41	3.74	4.00
cc. O_2 II	0.82	1.38	2.13	2.70	3.10	3.42	3.70	3.91

The data for both seasons show that fruit from the control had the lowest catalase activity and also that as the amount of nitrate used increases, the catalase activity increases until the highest amounts are reached, at which point there is a slight falling off. This is shown very well in Figure 24, which is a graph representing the average values for the 1929 season and in Figure 25, where the changes in catalase activity during the season are represented. An interesting confirmation of the nitrogen analyses is thus obtained (compare Figure 24 with Figure 8). There does not appear to be any correlation between the changes in the percentage of nitrogen throughout the season for each treatment and the catalase reaction (compare Figures 10 and 25). It is difficult to say why this should be. There is the possibility that, due to some factor in connection with the catalase determination (for instance, variation in the room temperature at which the ground catalase sample was allowed to stand at different times during the summer), results obtained on one date should not be compared with those on another. However, the regularity of the curves in Figure 25 might indicate that this was not true. It is interesting that each curve rises to a maximum on August 12 and then sharply declines. What this means is not evident at the present time; it can only be suggested that changes in the metabolism or permeability of the cells as the fruit approaches maturity may have an injurious effect on the catalase. Neither the hydrogen-ion concentration nor the total acid data throw any light on the question.

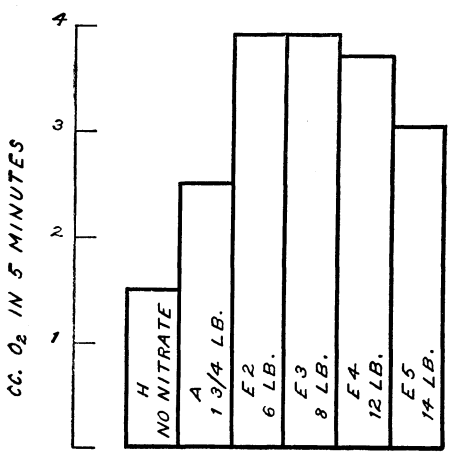

Fig. 24.—Catalase activity of fruit, Stayman Block. Average values for 1929. For treatments see Figure 8.

As a matter of interest, one set of catalase determinations was made on leaves from the Stayman block. The results are given in Table 3. As would be expected from the work of others, there is a marked difference in catalase activity between the control and nitrate treatments. The catalase activity of the sample from tree E 3 is over three times as great as the control. As in the case of the fruit from this same orchard, the catalase shows a rather uniform increase up to 8 pounds of nitrate per tree, after which there is a decrease. (See Fig. 26). In keeping with this, it will be observed from Table 3 that the weights of the 30 discs cut from the leaves for the catalase determinations are almost inversely proportional to their catalase activity. This is of interest in showing the type of growth resulting from the various treatments or in indicating the effect of the treatments on the translocation of carbohydrates from the leaves. With nitrate applications, either a thinner leaf is produced or else translocation of carbohydrates is facilitated.

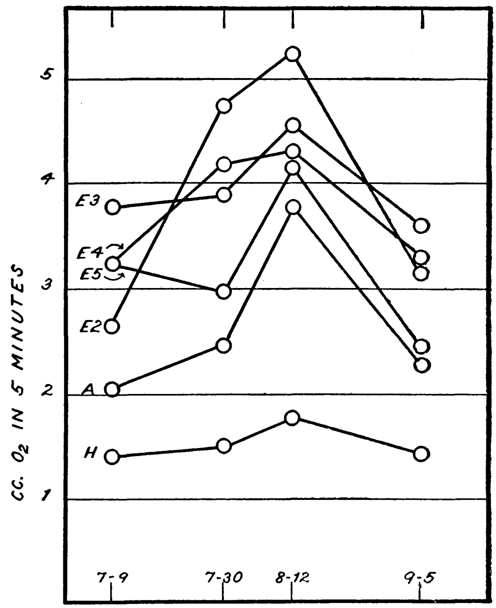

Fig. 25.—Changes in the catalase activity during the 1929 season. Stayman Block. For treatments see Figure 8.

Catalase determinations for Wealthy fruits from the East orchard are given in Table 15 and Figure 27. With one exception, the catalase activity is higher in all treated rows than in the control.

Two sets of catalase determinations were made on fruit of Stayman trees from the East orchard. One set of these determinations is unreliable because of difficulties with the apparatus, and the other set does not show any significant difference between the treated rows and the control, (Tables 17 and 18).

Results on the Stayman, pruning and fertilizer block show an increase in catalase in fruit from the treated row over the control and also a marked increase in the catalase from the leaves of the treated over the control, as is shown in Table 20.

An inspection of Tables 9, 10, 11, and 12 will show that the catalase activity in Jonathan fruits from the West orchard has no definite relation to the nitrate applications. This may be explained on the basis of the conditions in the orchard, already discussed, which offset to a considerable extent the effect of the treatments.

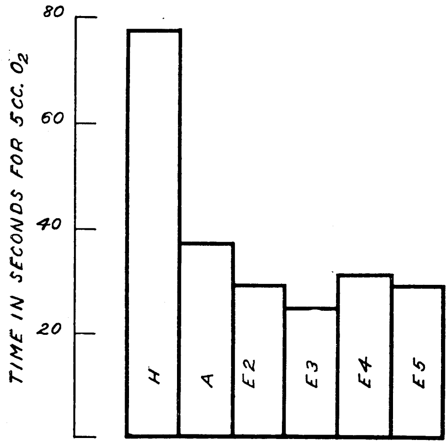

Fig. 26.—Catalase activity of leaves. Stayman Block, 9-6-28. For treatments see Figure 8

Sufficient evidence, however, has been presented to show that the nitrate treatments do result in an increase in the catalase activity of the fruit.

Hydrogen-ion concentration.—Little variation was found in the hydrogen-ion concentration of the expressed juice of apple fruits, either for different nitrate treatments or for different times during the season. The values were all very close to pH 3.20; for instance, in the Stayman Block the greatest variation between two individual determinations was 0.2 of a pH unit, but usually the variations were only a few hundredths of a unit from pH 3.20. It does not seem that the small variation found would have any physiological significance but some of the average values will be given as a matter of record. The individual determinations will be found in the tables. The average pH values for the Stayman Block for 1929 are shown in table on page 35.

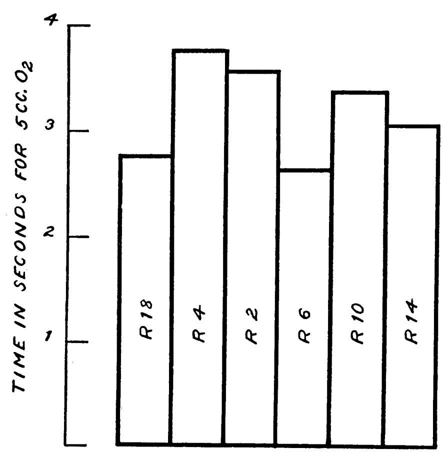

Fig. 27.—Catalase activity of fruit, Wealthy, East Orchard, 8-20-28. For treatments see Figure 12

From these data, the hydrogen ion appears to have its lowest concentration in the control and to increase with increasing amounts of nitrate up to 8 pounds per tree and then to decrease again; but it is very doubtful if the results are significant.

Row and tree	H	A	E 2	E 3	E 4	E 5
Treatment— Lb. $NaNO_3$ per tree	None	1¾	6	8	12	14
Average pH	3.275	3.220	3.215	3.207	3.210	3.265

Juice from Wealthy apples shows a greater hydrogen-ion concentration than the Stayman having a value of about pH 3.05 (Table 15), but there is no significant variation with the treatments. Stayman trees in the East orchard show an average value of about 3.20, also with no significant variation with the nitrate treatments. Jonathan fruits from the West orchard seem to show a higher pH value for the 1928 season than for 1929, but here again there is no relation to the amount of nitrate fertilizer used.

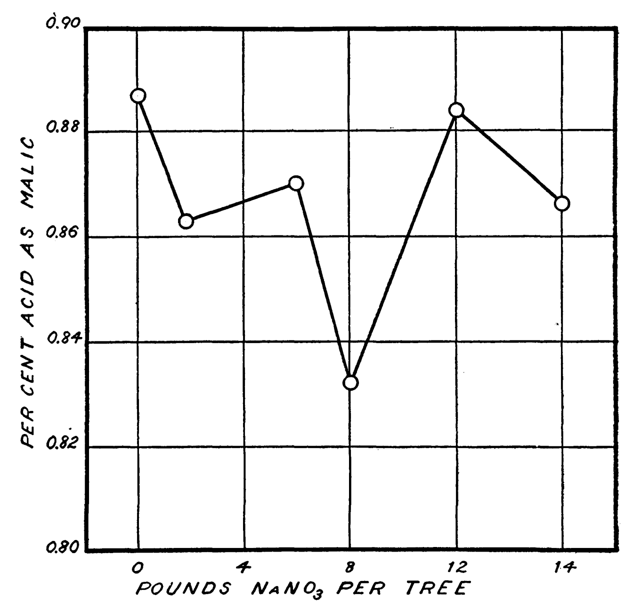

Fig. 28.—Total acid in fruit, Stayman Block. Average values for 1929

It is apparent then that the use of sodium nitrate, while having a marked effect in increasing the nitrogen content of the fruit and increasing its catalase activity, does not affect its hydrogen-ion concentration.

Total acid.—An examination of the data for total acid indicates that there is no constant relation between this and the hydrogen-ion concentration of the original juice but shows a possible correlation with the nitrate treatments in the Stayman Block where excessive nitrate was used. The average values of total acid for 1929 for this orchard are shown in Figure 28. The total acid, it will be noticed, is highest in the control, decreases to a minimum at 8 pounds of $NaNO_3$ per tree, and then increases with further increases in the amount of nitrate. What is believed to be an

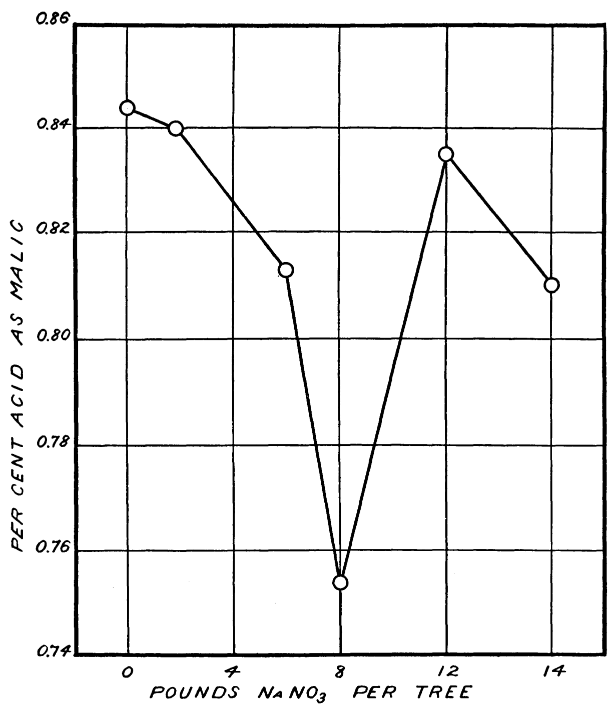

Fig. 29.—Total acid in fruit, Stayman Block. 8-12-29

exceptionally reliable set of titrations for August 12, 1929 is shown in Figure 29. This curve is very similar to the one representing the average values but is more regular. In this case also, the total acid is minimum at 8 pounds of nitrate per tree and bears an inverse relationship to the curves for nitrogen percentage and for catalase activity. Figure 30 gives the results of a very careful set of electrometric titrations made on the same date. From these curves one would conclude that, while there is little difference in the pH of the original juices, they show some variation in their buffer action. The control shows the greatest buffer action and tree E 3 the least. This again is correlated inversely with the percentage of nitrogen and the catalase activity of the fruit.

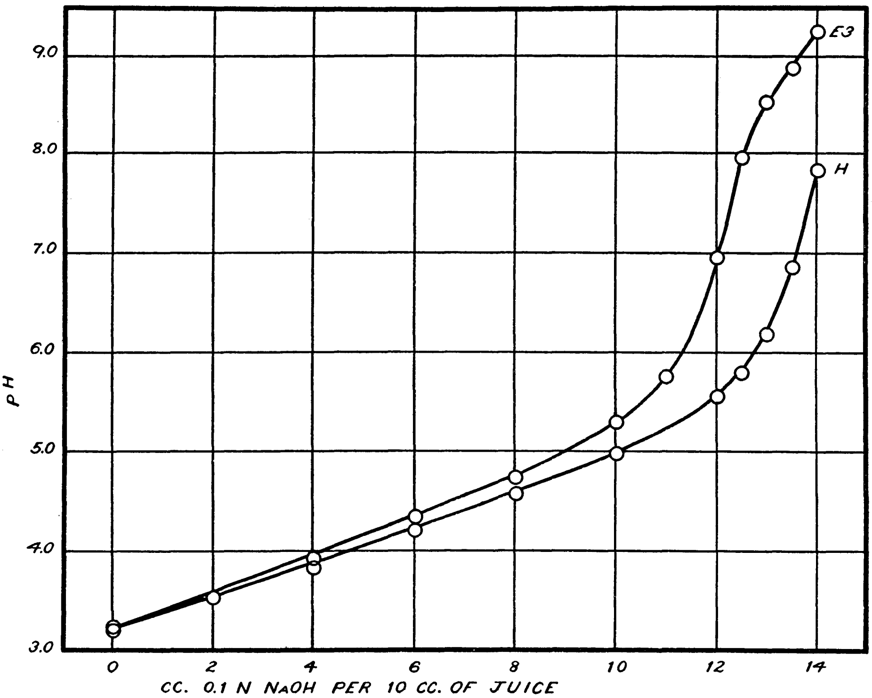

Fig. 30.—Titration curves of expressed juice, Stayman Block. 8-12-29. To avoid confusion only the curves for H and E 3 are given. The other curves have the same characteristics and are in the following order from H to E 3: A, E 4, E 2, E 5. The treatments are shown in Figure 8.

It is thought that these results for the Stayman Block should be regarded only as suggestive, since the other plots do not show any relation between the nitrate treatments and total acid. However, it should be remembered that in the latter case the treatments did not bring about such marked increases in nitrogen percentage or catalase activity.

For all the different treatments in the Stayman Block there is a general tendency for the total acid to decline as the season advances. This is shown very clearly in the average values for each sampling. These are plotted in Figure 31. The percentage of total acid decreases from 1.0% to 0.775%. The summarized data for total acids are given in Table V.

TABLE V.—Mature Stayman Trees in Sod—Total Acid

Row and tree	Treatment—Lb. $NaNO_3$ per tree	Per cent acid as malic			
		7-9-29	7-30-29	8-12-29	9-5-29
H	None	1.012	0.912	0.844	0.770
A	1¾	0.973	0.824	0.840	0.815
E2	6	0.990	0.948	0.813	0.728
E3	8	1.005	0.746	0.754	0.823
E4	12	1.013	0.929	0.835	0.759
E5	14	1.000	0.905	0.799	0.761

Soluble pectin.—Since the results obtained for soluble pectin in 1928 showed no significant variation with the nitrate treatments in any of the plots tested, determinations of this constituent were not carried out the following season. It would seem correct to say that the amount of soluble pectin is not a function of the nitrate treatment. From the data for the Jonathan variety (Tables 8-11) it would appear that the soluble pectin is high early in the season, is minimum towards the latter part of August, and then again begins to increase. This is shown in the average values for 1928 given below:

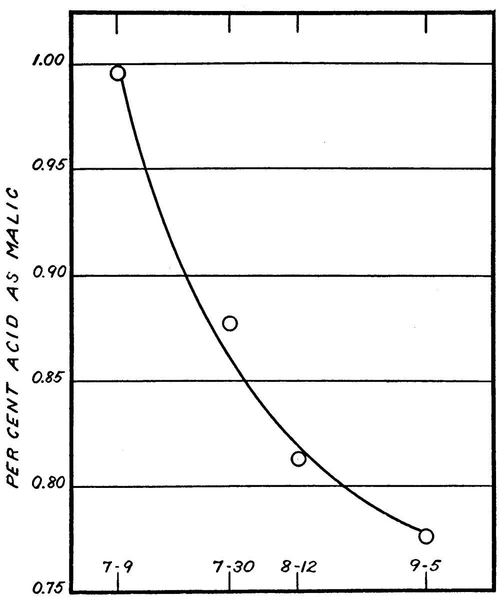

Fig. 31.—Changes in the total acid content for 1929. Average values. Stayman Block

As would be expected, the amount of soluble pectin also increases in storage as is shown in Table 24, but here again there is no relation to the nitrate applications.

Date	7-25-28	8-8-25	8-27-28	9-11-28
Average per cent of soluble pectin as calcium pectate	0.1222	0.0475	0.0338	0.0585

Respiration.—As in the case of pectin, respiration studies were only made during the 1928 season. These determinations were carried out on samples from the Stayman Block and from

Jonathan trees in the West orchard. The results will be found in Tables 2, 10, and 11. No constant relation between the respiration rate and the nitrate treatments is evident, whether the result is expressed as milligrams of CO_2 per hour or as milligrams of CO_2 per kilogram per hour. It should be recalled, of course, that these determinations were made on green fruit sampled during the summer.

Color.—Observation on color reported in connection with samples from the Stayman Block (Tables 1, 2, 5, and 6) show that in the control and in the normal nitrate treatments the fruits were more highly colored than in the high nitrate treatments. This may be due to a higher sugar concentration in the fruit from unfertilized trees or to a less amount of foliage as suggested by Burrell (5). Nightingale, Addoms, and Blake (31) have observed a greater coloration in peaches from low-nitrogen trees than from high-nitrogen trees. The control trees in the Stayman Block show only a sparse development of foliage, as compared with the high-nitrate trees.

Size of fruits.—Two methods of obtaining the size of fruits were used: the first consisted in measuring the diameter of each of the 15 fruits in a given sample and averaging the results obtained, and the second was to weigh carefully the sample (15 fruits) to the nearest gram. Measurements of the diameters were made only in 1928 and the data will be found in the tables.

TABLE VI.—Mature Stayman Trees in Sod—Size of Fruits

Row and tree	Treatment—Lb. $NaNO_3$ per tree	Weight of 15 fruits, in grams						
		7-31-28	9-6-28	7-9-29	7-30-29	8-12-29	9-5-29	Average 1929
H	None	658	1327	522	883	1217	1390	1011
A	1¾	642	1570	580	1016	1198	1968	1190
E 2	6	770	1695	656	1087	1262	1890	1224
E 3	8	758	1735	564	1036	1181	1950	1183
E 4	12	918	1821	661	1173	1437	1980	1313
E 5	14	836	1991	598	1119	1427	1885	1257

Fruits from the Stayman Block show, in general, an increase in diameter for the nitrate treatments as compared with the control. In the case of Jonathan fruits there is some variation.

A summary of the data for the weights of fruits from the Stayman Block is given in Table VI. The relation between the size of the fruit and the nitrate treatment is clear; the average values for 1929 show the lowest weight for the control and an increase in weight up to 12 pounds of sodium nitrate per tree.

In the case of the Jonathan fruits there is no distinct difference between the weights of fruit from the control and from the treated plots. Wealthy fruits show striking differences in weights between the control and the treated rows (See Table 15). For the samples taken August 15, 1929, the average difference in weight is 342 grams in favor of the treated row. The probable error of the difference between the control and the treated row is ±96.81 grams and the difference divided by this value $\left(\frac{d}{PE_d}\right)$ equals 3.53. Here again, as in the case of nitrogen, there appears to be a significant increase in favor of the nitrate fertilized trees.

Moisture and total solids.—In general, the results obtained with fruit from the Stayman Block show the most marked differences in water content between the controls and the treated trees. For 1928, as shown in Tables 1 and 2, there is, with one exception, a lower moisture content in fruits from the controls. In 1929 this difference is quite marked, as shown in Figures 32 and 33. In one case the percentage of moisture is given and in the other the percentage of solids. The amount of moisture is seen to increase to a maximum of 8 pounds of nitrate per tree and then to decline slightly. The total solids of course show the reverse. This is directly correlated with the nitrogen content of the fruit, catalase, and other determinations already discussed and indicates that the increase in the nitrogen in the fruit either brings about a greater absorption of water or decreases the transpiration rate. This, of course, may be associated with the denser foliage of the treated trees. Jonathan fruits for the 1928 season do not show any distinct difference. For 1929, the percentage of moisture was

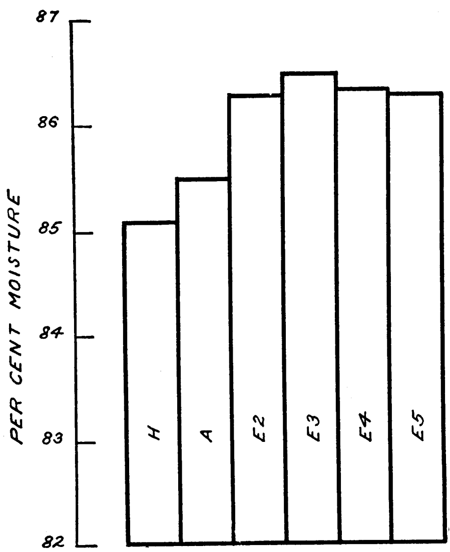

Fig. 32.—Moisture content of fruit, Stayman Block. Average values for 1929. The treatments are shown in Figure 8.

generally lower in the control than in the treated rows. In the Wealthy samples taken August 15, 1929 (Table 16) the average difference in favor of the treated row was 0.41%. This result, however, is not statistically significant since $\frac{d}{PE_d}$ is only about 1.8.

From the data on moisture, we would conclude that there are indications that the nitrate treatments increase the percentage of water in the fruit but that further studies should be made to decide this point.

In 1929, the moisture content of the fruit sampled July 9 was greater than that of the fruit sampled September 5, as shown by data from the Stayman block.

It is doubtful if there is any physiological significance in this decrease. It appears to bear a rather close correlation to the course of precipitation during this season. There was a fairly large amount of rain during the first part of July and during the rest of the month, very little. A deficiency of rainfall is recorded for the months of August and September.

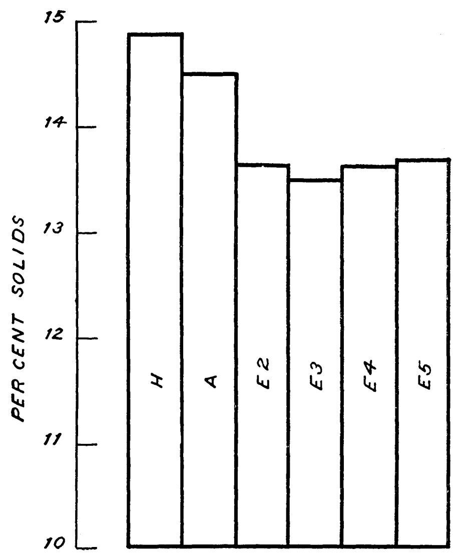

Fig. 33.—Total solids of fruit. Stayman Block. Average values for 1929. The treatments are shown in Figure 8.

Date	7–9	7–30	8–12	9–5
Average per cent of moisture........................	87.08	86.15	86.57	84.3

Carbohydrates.—These determinations were begun with the 1929 season and are not yet completed. The data will be reserved for future publication.

STORAGE INVESTIGATIONS

The crux of this whole matter and the final objective in the investigation were to determine whether apples from trees receiving varying amounts of nitrogen will behave differently in storage. It has already been shown in the previous section of this paper that the different lots of apples did contain nitrogen roughly in proportion to the amount applied to the trees. The material used in storage tests, then, actually represented the types of apples which should show physiological breakdown due to high nitrogen content or no breakdown due to low nitrogen, provided this factor is the cause of such breakdown. A partial report has already been made of the results (14) and certain of the data are again included here.

A preliminary and incomplete test was made in 1927. Fruit from more plots was placed in storage in 1928, 1929, and 1930, so that a record is available for four seasons of fruit from trees that have had small and large amounts of nitrate of soda. The results, while showing some variation, indicate, in the main, that there is no correlation between total nitrogen content and the keeping quality of the fruit.

THE STAYMAN ORCHARD

As indicated above, this orchard has been continuously in sod and, hence, shows a marked effect in growth and yield from the treatments with nitrogen fertilizers. (Figs. 3 and 4). Likewise, the flesh of the apples is markedly higher in total nitrogen in the treated plots (Figs. 8 and 9). Table VII shows the amount of decay or breakdown of apples from the trees receiving differential treatments.

It is clear from these data that the fruit from the growing season of 1929 broke down in storage much more than that from

TABLE VII.—Per Cent of Decay or Breakdown of Stayman Winesap Apples in Storage

(Trees planted 1915; grown in sod)

April, 1927		April, 1928		April, 1929		April, 1930	
$NaNO_3$	Breakdown	$NaNO_3$	Breakdown	$NaNO_3$	Breakdown	$NaNO_3$	Breakdown
Lb.	*Pct.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*
2¾	1.6	3	4.1	3¼	0.0	3½	7.9
....	....	6	0.86	7	0.4	7	9.9
....	....	8	0.7	10	0.5	10½	.6
....	....	12	0.0	14	0.0	....	15.3
12	4.9	14	2.2	17½	0.0	18	.4
....	....	....	....	None	0.0	None	39.5

the other years during the test. However, it would be difficult to conclude from these results that increasing amounts of nitrogen induced more breakdown than small amounts or that any amount of nitrogen, applied as a fertilizer, induced more breakdown than occurred where no nitrogenous fertilizer was applied and the naturally occurring soil nitrates were low.

It is true that the red color of the fruit is reduced by the use of nitrogen, more under some conditions than others and more with some varieties than others. As a result there is a greater amount of scalding of the fruit in storage, as shown by the following figures for fruit grown in the seasons of 1928 and 1929.

	Percentage of scald in storage	
	1928	1929
Average unfertilized trees	14.2	20.4
Average normal nitrate	55.2	50.2
Approximately double nitrate	40.6	38.0
Approximately triple nitrate	56.0	23.7
Approximately quadruple nitrate	....	17.7
Approximately 5 times normal	62.0	29.6

That the amount of scald can be materially lessened by wrapping the apples in oiled paper wraps is shown by the following observations of apples in storage from the 1926 crop and the final records made on April 7, 1927.

	Tree-run fruit	Percentage scald
1 bushel	Oiled paper	.9
1 bushel	Plain tissue	21.3
1 bushel	Not wrapped	25.0

It should not be inferred that this large reduction in scald could be expected regularly but these records do represent an approximation of what may be expected from the use of oil-impregnated paper.

THE WEST ORCHARD

The situation in this orchard is in marked contrast to that in the Stayman orchard. The trees are younger by 7 years, are cultivated instead of in sod land, and the varieties include Grimes Golden, Jonathan, and McIntosh, as well as Stayman Winesap. Each plot in the orchard receives the same total amount of nitrate of soda, with the exception of one which is untreated. The difference in treatment consists in the time of application, as shown in

Table VIII. Considerable importance has been attached to the time of application; for, if the trees are supplied with a soluble form of nitrogen in June or August, the effect on keeping quality and color might be quite different than that induced by April applications.

As will be seen from Table VIII, there was more decay in the 1928 crop of Grimes Golden where no treatment had been given than elsewhere (15.4%). The next highest amount was in Plot 6 where the applications were made in April and August; while the average of the four treatments applied in April (that is, the usual time) was 5.2%. The next year breakdown was prevalent and the untreated plot (2) showed 5.3% at the end of the storage season in April. The largest amount was in Plot 4 where the treatment was made in August (9.1%), while the average of the April treated plots was 1.7% breakdown. It seems doubtful if any significance should be attached to the variation in decay and breakdown between the plots, unless it be that the untreated ones seem to be inferior in this respect to the treated ones.

From the 1928 crop, the Jonathan (Table VIII) showed the greatest amount of decay resulting from the August treatment. The weather was quite dry following the fertilizer application, and it is questionable if the fruit was affected by the treatment. The average of the April treatments was 1.8% decay. In the 1929 crop, there is a great deal of variation in the amount of breakdown, varying in the April treated plots from 0.8% to 8.6%, which represents a wider range than between any of the other plots.

The McIntosh samples, likewise, showed a variation in decay to which no significance could be attached.

The Stayman Winesap in this orchard showed no decay in the 1928 crop and only a small amount of decay and breakdown in the 1929 crop. The untreated plot showed a total of 0.8% breakdown at the end of the storage season (April), while the average of the plots receiving the normal application of nitrate of soda in April showed a total of 2.0% breakdown. However, the latter plots varied from 0.4 to 4.7%, thus making such a variation as to render the results of doubtful significance from the standpoint of nitrogen applications.

The amount of scald, however, was significantly less among apples from the untreated plot. This situation has been true generally throughout the experiment, and, as mentioned above, emphasizes the need of using oiled wrappers.

THE EAST ORCHARD

The varieties included in the storage test from this orchard were Stayman Winesap and Wealthy, one a long-keeping sort and the other a fall apple. There was little decay or breakdown in

TABLE VIII.—Storage Results, 1928 and 1929 Crop

With fruit from West Orchard, planted 1922

Treatment	Plot	Per cent decay, April 1929	Per cent decay, April 1930	Per cent breakdown, April 1929	Per cent breakdown, April 1930	Per cent scald, April 1929	Per cent scald, April 1930
Grimes							
Normal nitrate, April	1	5.3	1.9	0	2.3	13.4	66.4
Not fertilized	2	15.4	3.7	0	5.3	11.2	55.8
Normal nitrate, April	3	2.8	1.5	0	2.0	22.7	54.1
Normal nitrate, August	4	8.1	3.2	0	9.1	26.7	73.3
Normal nitrate, April	5	6.2	1.5	0	1.9	39.8	61.5
Normal nitrate, ½ April, ½ August	6	13.9	1.3	0	1.3	24.8	63.1
Normal nitrate, April	7	3.2	.5	0	.5	28.6	54.7
Normal nitrate, September	8	6.0	3.3	0	5.7	23.9	54.1
Average normal nitrate, April	....	5.2	1.3	0	1.7	28.6	59.4
Jonathan							
Normal nitrate, April	1	.9	0	0	8.6	2.8	0
Not fertilized	2	1.5	0	0	3.5	1.7	0
Normal nitrate, April	3	1.3	0	0	5.6	14.7	0
Normal nitrate, August	4	6.8	0	0	.8	14.2	0
Normal nitrate, April	5	2.2	0	0	.8	15.5	0
Normal nitrate, ½ April, ½ August	6	3.4	0	0	1.2	5.9	0
Normal nitrate, April	7	2.7	0	0	5.2	7.2	0
Normal nitrate, September	8	1.3	0	0	3.3	2.6	0
Average normal nitrate, April	....	1.8	0	0	4.9	11.8	0
McIntosh							
Normal nitrate, April	1	11.8	2.1	0	0	....	....
Not fertilized	2	17.7	0	0	0	....	....
Normal nitrate, April	3	18.3	1.0	0	0	....	....
Normal nitrate, August	4	4.9	0	0	.5	....	....
Normal nitrate, April	5	12.7	1.1	0	0	....	....
Normal nitrate, ½ April, ½ August	6	18.6	.6	0	0	....	....
Normal nitrate, April	7	9.5	0	0	0	....	....
Normal nitrate, September	8	20.2	0	0	0	....	....
Average normal nitrate, April	....	13.1	.9	0	0	....	....
Stayman							
Normal nitrate, April	1	0	.7	0	2.0	0	20.5
Not fertilized	2	0	0	0	.8	0	17.1
Normal nitrate, April	3	0	.8	0	.4	0	26.7
Normal nitrate, August	4	0	0	0	7.5	0	24.0
Normal nitrate, April	5	0	.3	0	1.4	0	34.5
Normal nitrate, ½ April, ½ August	6	0	.7	0	1.1	0	30.8
Normal nitrate, April	7	0	.8	0	4.7	0	28.5
Normal nitrate, September	8	0	.4	0	2.2	0	21.1
Average normal nitrate, April	....	0	.7	0	2.0	0	28.6

either the 1928 or 1929 Stayman crop. A survey of the figures (Table IX) shows only 0.4% decay of the apples treated with the normal nitrate in 1929; while those treated with three times this amount showed none at the end of the storage season; and the complete fertilizer plot, 0.4%. It is impossible in this cultivated orchard to associate breakdown or decay with the fertilizer treatment. In the latter season, there was some breakdown in the Station orchards, which included Stayman as well as other varieties.

TABLE IX.—Storage Results, 1928 and 1929 Crops

With fruit from cultivated orchard, planted 1922

Treatment	Plot	Per cent decayed		Per cent scalded	
		April		April	
		1928	1929	1928	1929
Stayman:					
5¼ lb. nitrate	1	0	0	15.3	8.0
1¾ lb. nitrate	2	0	.4	22.4	6.2
Complete fertilizer	3	0	.4	31.5	4.3
1¾ lb. nitrate	4	0	1.1	14.3	10.1
Nitrate and Superphosphate	5	1.0	0	12.1	8.3
1¾ lb. nitrate	6	0	0	5.1	12.8
Nitrate and mur. potash	7	0	0	10.7	10.4
1¾ lb. nitrate	8	0	.3	6.8	9.1
No fertilizer	9	0	0	6.1	1.2
1¾ lb. nitrate	10	0	0	0	.8
Average of normal N	....	0	.4	9.7	7.9
		Nov. 1928	Jan. 1929	Nov. 1928	Jan. 1929
Wealthy:					
5¼ lb. nitrate	1	10.2	2.0	0	0
1¾ lb. nitrate	2	13.9	1.9	0	0
Complete fertilizer	3	15.8	2.8	0	0
1¾ lb. nitrate	4	10.8	1.5	0	0
Nitrate and Superphosphate	5	6.9	1.9	0	0
1¾ lb. nitrate	6	17.4	2.8	0	0
Nitrate and mur. potash	7	10.1	1.9	0	0
1¾ lb. nitrate	8	0	.9	0	0
No fertilizer	9	15.9	0	0	0
Average of normal N	....	10.5	1.8	0	0

The Wealthy, which is not a long-keeping apple, was held until the middle of January. By that time the sample lots were showing considerable decay. The average decay in the normal nitrate plots was 10.5% in 1928 and 1.8% in the 1929 crop. The untreated plot showed 15.9% in 1928 and none in 1929. The excess-nitrogen plot showed 10.2% decay in 1928 and 2.0% in 1929. The plots treated with other elements, in addition to nitrogen, showed no significantly better results; this result is in line with the other data assembled to date.

DISCUSSION

The purpose of undertaking the chemical and physiological studies was to ascertain if, and to what extent, nitrogen (in the form of Chilean sodium nitrate) applied to apple trees was taken into the fruit and what chemical or physiological changes it would bring about which might result in a condition favorable for the development of physiological breakdown in storage. If these storage studies showed any correlation between breakdown and the nitrate treatments, a possible cause of this condition might be evident. This did not prove to be the case. Storage studies over a number of years, including those in which breakdown was prevalent, have shown that there is no correlation between the nitrate treatments and physiological breakdown. At the same time, the chemical studies have shown that the nitrate treatments have marked physiological effects on the fruit. There are also beneficial effects, such as increase in growth, in yield, and often in size of fruits.

Aside from any possible relation to physiological breakdown, it is to be hoped that the results of this investigation will be of interest in showing the effect of nitrate applications on the fruit and also seasonal changes in the chemistry and physiology of the fruit containing various amounts of nitrogen.

From the summaries of data presented under "Results", there is little doubt that the use of nitrate causes an increase in the amount of total nitrogen in the fruit as is shown very clearly in the samples taken from the Stayman Block. It is also supported by data from the other orchards, including a statistical examination of the results from Wealthy trees. It is also to be seen that the results obtained when fertilizer is applied to trees under cultivation are not so marked as when applied to trees in sod. As a result of the greater nitrogen content, a change is brought about in the metabolism of the fruit. This is reflected in a marked increase in the catalase activity of the tissue which is directly correlated with the percentage of nitrogen. While many experiments have been reported in the literature showing increases in the catalase activity of apple leaves through nitrate fertilization, this is thought to be the first report showing similar increases in the fruit. It has been shown that the size of the fruits is increased, the coloration is frequently less, and that probably the moisture content is higher, when nitrate is applied.

Although the hydrogen-ion concentration is remarkably constant for a given variety regardless of the treatment, there are indications that the total acid content decreases to a minimum as the amount of nitrate is increased (up to 8 pounds of fertilizer per tree) and then increases with the application of greater amounts of nitrogen, thus showing an inverse relation to the nitrogen content of the fruit and the catalase activity. Buffer action of the juice seems to be lower with increasing nitrate. According to Haynes (17), apples which keep well in storage are those which lose acid slowly. It has already been shown that there is a marked decline in the average values for total acid in samples from the Stayman block. However, the declines for the different plots bear no relation to the nitrate treatments (See Table V). While Miss Haynes' results apply to apples in storage, our data on total acids during the growing season could indicate no possible relation between keeping quality and the amount of nitrate per tree.

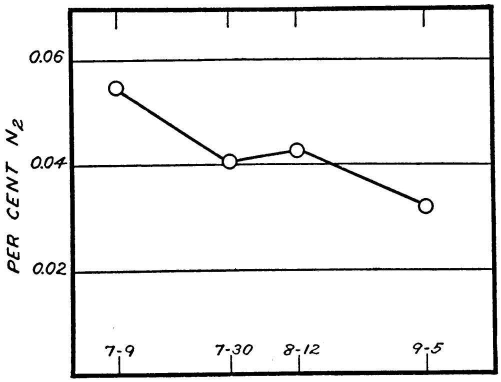

Fig. 34.—Seasonal changes in the percentage of nitrogen, Stayman Block. Average values for 1929

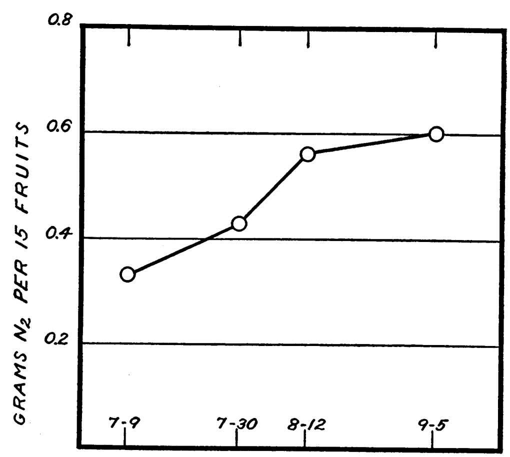

Fig. 35.—Seasonal changes in the grams of nitrogen per 15 fruits. Stayman Block. Average values for 1929

The respiration rate of the fruit does not increase with increasing percentages of nitrogen in the fruit as one might expect it would from the work of Archbold (3, 4) and of Kidd and West (24). Nor is there any relationship between the respiratory rate during the growing season and the keeping quality of the fruit, as has been shown by Kidd and West (25) for apples in storage.

Increases in soluble pectin which might indicate a tendency towards early maturity of the fruit were not found as a result of the nitrate treatments. A number of workers have shown that with ripening there are increases in the amount of pectin. Carré (6, 7), for instance, has shown this for apples in storage; Appleman and Conrad (1, 2) for peaches in storage and tomatoes on the vine; and Emmet (11, 12) for pears. Haller (15), however, has shown that apples maturing on the tree, while they show softening as indicated by pressure tests, have a small but constant amount of pectin; although, at the same time, there is a decrease in the protopectin and total pectic material. He thinks, however, that this is only an apparent decrease due to the increased size of the fruit.

Besides the effect of nitrate treatments it may be well also to summarize the seasonal changes which occur in the apple fruits. These various changes which have been noted previously in this bulletin have been obtained in most cases by averaging the results of analyses made on samples taken on a given date, including all treatments. As the season progresses there is a falling off in the percentage of nitrogen in the fruit (Fig. 34); while at the same time the total amount of nitrogen increases to about the middle of August after which it remains constant (Fig. 35). The catalase content increases to the middle of August and then falls off. The hydrogen-ion concentration remains remarkably constant throughout the season; while the total acid decreases in a regular manner (See Fig. 31). The per cent of soluble pectin appears to decrease up to the latter part of August and then to increase. The moisture content decreased in 1929, but this may be associated with a drop in the amount of rainfall that season.

SUMMARY

1. Chilean sodium nitrate applied to apple trees, both in cultivation and in sod, resulted in an increase in the percentage of total nitrogen in the fruit and also in an increase in the total amount of nitrogen per apple. The results with trees in sod were more striking than with those in cultivation; although for trees in cultivation the increase in the treated over the control was found to be significant.

2. For trees in sod there was a gradual decrease in the percentage of nitrogen of the fruit throughout the season for all treatments and the control, while the total amount of nitrogen per apple

fruit increased. In the control this latter value became constant about the middle of the summer while in fruit from the nitrate-treated trees the total amount of nitrogen per apple continued to increase throughout the season.

3. The catalase activity of the fruit tissue was much higher in the case of the nitrate treatments than in unfertilized plots, and again the difference was much more striking for trees in sod. There was a remarkable correlation between the percentage of nitrogen in the fruit and the catalase activity. The catalase activity of the leaves was examined in two cases and the findings of others showing an increase in this reaction with nitrate fertilization were confirmed. A close correlation was found between these determinations and those made on the fruit and with the percentage of nitrogen in the fruit.

4. The hydrogen-ion concentration of the juice did not appear to be affected by the application of nitrate, while the total acid decreased to a minimum at 8 pounds of sodium nitrate per tree and again increased as the amount of nitrate was further increased. It is thought that the buffer action of the juice of apples from nitrate-treated trees is less than that of fruit from the controls. The total acid content of the fruit for all treatments decreased as the season advanced although the decrease bears no relation to the treatment.

5. No relationship was found to exist between nitrate applications to the trees and the rate of respiration of the fruit.

6. Determinations of soluble pectin indicated no correlation between this and the nitrate applications.

7. Fairly marked increases in the moisture content of the fruit were obtained for Stayman trees in sod as a result of nitrate fertilization, and they show a direct correlation with the percentages of nitrogen. For other plots the relation of moisture to nitrogen was not well defined. As the season advanced, there was a gradual decrease in the average moisture content for all treatments.

8. Nitrate fertilization was found to decrease the coloration of the fruit, resulting in greater scald in storage.

9. There has been no consistent relation between the fertilizer applications and the amount of decay or physiological breakdown in the orchards under study. It is particularly pointed out that no amount of nitrate of soda used has induced breakdown of the fruit.

10. The usual beneficial effects to growth and yield of the trees followed the use of nitrate of soda.

TABLE 1.—Stayman Block, July 31, 1928

Row and tree	Treatment —Lb. $NaNO_3$ per tree	Color	Average diameter cm.	Weight 15 fruits gm.	H_2O %	Nitrogen		Catalase cc. O_2 5 min.
						%	Gm. per 15 fruits	
H	None	* * * *	4.37	658	86.7	0.0339	0.2231	1.64
A	1¾	* * *	4.17	642	87.6	0.0308	0.1979	2.56
E2	6	*	4.53	770	88.0	0.0444	0.3422	3.20
E3	8	*	4.50	758	87.6	0.0505	0.3829	3.47
E4	12	*	4.87	918	88.2	0.0428	0.3931	2.15
E5	14	* *	4.80	836	87.7	0.0414	0.3457	2.34

TABLE 2.—Stayman Block, September 6, 1928

Row and tree	Treatment —Lb. $NaNO_3$ per tree	Color	Average diameter (15 fruits) cm.	Weight 15 fruits gm.	H_2O %	Nitrogen		Catalase cc. O_2 5 min.	Respiration		Soluble pectin %	pH juice
						%	Gm. per 15 fruits		CO_2, Mg. per hr.	CO_2 M-K-H		
H	None	* * * *	5.67	1327	86.9	0.0192	0.2542	2.90	20.2	15.2	0.0354	3.20
A	1¾	* * * *	6.13	1570	87.1	0.0234	0.3673	4.75	21.6	13.7	0.0464	3.25
E2	6	* *	6.27	1695	87.7	0.0297	0.5043	5.50	25.4	14.5	0.0324	3.24
E3	8	*	6.13	1735	87.3	0.0297	0.5159	5.40	22.9	13.2	0.0300	3.21
E4	12	*	6.33	1821	87.6	0.0295	0.5364	4.64	26.2	14.4	0.0264	3.24
E5	14	* * *	6.23	1991	86.9	0.0260	0.5182	3.60	27.5	13.8	0.0390	3.26

TABLE 3.—Stayman Block, Catalase of Leaves, September 6, 1928

Row and tree	H	A	E 2	E 3	E 4	E 5
Weight of 30 discs of leaves, grams....	0.620	0.525	0.475	0.425	0.465	0.595
Catalase, seconds for 5 cc.............	78	37.5	29.7	25.2	31.7	29.7

TABLE 4.—Stayman Block, July 9, 1929

Row and tree	Treatment—Lb. $NaNO_3$ per tree	Weight 15 fruits gm.	H_2O %	Nitrogen %	Nitrogen Gm. per 15 fruits	Catalase cc. O_2 5 min.	pH juice	Total acid, % as malic
H	None	522	85.8	0.0350	0.1827	1.39	3.27	1.012
A	1¾	580	86.6	0.0439	0.2546	2.04	3.29	0.973
E 2	6	656	87.4	0.0470	0.3083	2.66	3.27	0.990
E 3	8	564	87.7	0.0764	0.4309	3.78	3.23	1.005
E 4	12	661	87.7	0.0593	0.3920	3.23	3.25	1.013
E 5	14	598	87.3	0.0659	0.3941	3.21	3.30	1.000

TABLE 5.—Stayman Block, July 30, 1929

Row and tree	Treatment—Lb. $NaNO_3$ per tree	Color	Weight 15 fruits gm.	H_2O %	Nitrogen %	Nitrogen Gm. per 15 fruits	Catalase cc. O_2 5 min.	Sp. Gr. juice	Solids in juice %	pH juice	Total acid, % as malic
H	None	* * *	883	84.7	0.0311	0.2747	1.51	1.035	8.78	3.38	0.912
A	1¾	0	1016	85.7	0.0338	0.3434	2.46	1.037	9.25	3.17	0.824
E 2	6	0	1087	86.6	0.0449	0.4881	4.75	1.034	8.50	3.17	0.948
E 3	8	*	1036	86.3	0.0481	0.4868	3.90	1.035	8.78	3.20	0.746
E 4	12	0	1173	86 9	0.0440	0.5162	4.18	1.034	8.50	3.20	0.929
E 5	14	0	1119	86.7	0.0418	0.4677	2.94	1.034	8.50	3.28	0.905

TABLE 6.—Stayman Block, August 12, 1929

Row and tree	Treatment —Lb. $NaNO_3$ per tree	Color	Weight 15 fruits gm.	H_2O %	Nitrogen %	Nitrogen Gm. per 15 fruits	Catalase cc. O_2 5 min.	Sp. Gr. juice	Solids in juice %	pH juice	Total acid, % as malic
H	none	* * * *	1217	85.8	0.0275	0.335	1.78	1.033	8.26	3.24	0.844
A	1¾	* * *	1198	86.4	0.0309	0.370	3.79	1.035	8.78	3.16	0.840
E2	6	0	1262	86.8	0.0469	0.592	5.23	1.031	7.78	3.20	0.813
E3	8	0	1181	86.8	0.0581	0.686	4.54	1.032	8.03	3.19	0.754
E4	12	0	1437	86.7	0.0480	0.690	4.30	1.031	7.78	3.19	0.835
E5	14	0	1427	86.9	0.0483	0.689	3.67	1.031	7.78	3.22	0.799

TABLE 7.—Stayman Block, September 5, 1929

Row and tree	Treatment – Lb. $NaNO_3$ per tree	Weight 15 fruits gm.	H_2O %	Nitrogen %	Nitrogen Gm. per 15 fruits	Catalase cc. O_2 5 min.	Sp. Gr. juice	Solids in juice %	pH juice	Total acid, % as malic
G	none	1390	84.2	0.0217	0.302	1.41	1.041	10.2	3.20	0.770
A	1¾	1968	83.2	0.0232	0.457	2.29	1.045	11.2	3.26	0.815
E1	6	1890	84.6	0.0323	0.610	3.15	1.039	9.7	3.22	0.728
E2	8	1950	85.1	0.0363	0.708	3.60	1.041	10.2	3.21	0.823
E3	12	1980	84.1	0.0412	0.816	3.28	1.041	10.2	3.20	0.759
E5	14	1885	84.6	0.0363	0.684	2.45	1.040	10.0	3.26	0.761

TABLE 8.—Jonathan, West Orchard, July 25, 1928

Row	Treatment—$NaNO_3$	Av. diam. fruits cm.	Weight 15 fruits gm.	H_2O %	Catalase cc. O_2 5 min.	Soluble pectin as Ca pectate per 100 gm. gm.
3	None	4.07	520	88.9	3.55	0.1020
5	1¾ lb. April	3.90	489	88.7	8.73	0.1250
7	1¾ lb. August	4.03	528	86.6	2.99	0.1620
11	⅞ lb. April ⅞ lb. August	3.83	525	88.4	4.22	0.1000

TABLE 9.—Jonathan, West Orchard, August 8, 1928

Row	Average diam. cm.	Weight 15 fruits gm.	H_2O %	Nitrogen %	Nitrogen Gm. per 15 fruits	Catalase cc. O_2 5 min.	pH juice	Total acid, % as malic	Soluble pectin as Ca pectate %
3	4.80	804	88.0	0.0422	0.3393	2.70	3.23	0.84	0.0370
5	4.83	855	88.3	0.0497	0.4293	1.98	3.17	0.87	0.0550
7	4.90	904	88.4	0.0453	0.4133	2.73	3.24	0.80	0.0550
11	4.73	812	88.3	0.0445	0.3614	2.47	3.22	0.82	0.0420

TABLE 10.—Jonathan, West Orchard, August 27, 1928

Row	Average diam. cm.	Weight 15 fruits gm.	H_2O %	Nitrogen %	Nitrogen Gm. per 15 fruits	Catalase cc. O_2 5 min.	pH juice	Total acid, % as malic	Soluble pectin as Ca pectate %	Respiration CO_2 Mg. per hr.	Respiration CO_2 M-K-H
3	5.63	1318	86.9	0.0386	0.5087	5.45	3.17	0.763	0.0350	36.3	27.5
5	5.63	1287	86.9	0.0419	0.5392	4.67	3.17	0.719	0.0400	32.2	25.0
7	5.43	1226	86.9	0.0369	0.4524	5.35	3.17	0.710	0.0350	33.9	27.6
11	5.77	1407	87.0	0.0469	0.6598	5.29	3.18	0.740	0.0254	35.0	24.9

TABLE 11.—Jonathan, West Orchard, September 11, 1928

Row	Average diam. cm.	Weight 15 fruits gm.	H_2O %	Nitrogen %	Nitrogen Gm. per 15 fruits	Catalase cc. O_2 5 min.	pH juice	Total acid, % as malic	Soluble pectin as Ca pectate %	Respiration CO_2 Mg. per hr.	Respiration CO_2 M-K-H
3	6.31	1714	86.5	0.0323	0.5536	6.29	3.11	0.7371	0.0660	40.1	23.4
5	6.17	1616	87.0	0.0369	0.5963	5.37	3.10	0.6778	0.0660	40.4	25.0
7	5.90	1495	86.8	0.0329	0.4919	4.81	3.11	0.7018	0.0500	39.2	26.0
11	6.03	1580	86.7	0.0343	0.5420	5.50	3.11	0.7396	0.0520	40.0	25.3

TABLE 12.—Jonathan, West Orchard, July 23, 1929

Row	Treatment $NaNO_3$	Weight 15 fruits gm.	H_2O %	Nitrogen		Catalase cc. O_2 5 min.	Sp. gr. juice	Solids in juice %	pH juice	Total acid, % as malic
				%	Gm. per 15 fruits					
3	None	824	86.1	0.0506	0.4169	2.71	1.036	9.0	3.12	1.11
5	1¾ lb. April	703	86.4	0.0571	0.4014	3.24	1.035	8.8	3.10	1.09
7	1¾ lb. August	755	85.5	0.0499	0.3767	2.63	1.039	9.7	3.11	1.12
11	⅞ lb. April and ⅞ lb. August	756	86.4	0.0343	0.2593	2.58	1.031	7.8	3.11	1.10
15	1¾ lb. previous fall	863	86.1	0.0632	0.5454	2.80	1.034	8.5	3.14	1.10

TABLE 13.—Jonathan, West Orchard, August 2, 1929

Row	Weight 15 fruits gm.	H_2O %	Nitrogen %	Nitrogen Gm. per 15 fruits
3	872	86.3	0.0406	0.3540
5	868	86.6	0.0549	0.4765
7	875	85.3	0.0417	0.3649
11	810	86.5	0.0492	0.4027
15	1035	85.8	0.0564	0.5837

TABLE 14.—Jonathan, West Orchard, August 26, 1929

Row	Weight 15 fruits gm.	H_2O %	Nitrogen %	Nitrogen Gm. per 15 fruits
3	1244	84.8	0.0214	0.2662
5	1386	85.7	0.0463	0.6417
7	1268	84.8	0.0319	0.4046
11	1417	85.1	0.0428	0.6063
15	1530	85.1	0.0400	0.6120

TABLE 15.—Wealthy, East Orchard, August 20, 1928

Row	Treatment— $NaNO_3$	Average diam.	Weight 15 fruits	H_2O	Nitrogen		Catalase cc. O_2	pH juice	Total acid, % as malic	Soluble pectin as Ca pectate	Respiration	
		cm.	gm.	%	%	Gm. per 15 fruits	5 min.			%	CO_2 Mg. per hr.	CO_2 M-K-H
2	5¼ lb.	6.23	1743	89.3	0.0384	0.6693	3.59	3.06	0.87	0.0584	43.7	25.0
4	1¾ lb.	6.57	1939	89.3	0.0323	0.6263	3.79	3.03	0.83	0.0450	42.9	22.1
6	Complete fertilizer	6.44	1820	89.2	0.0377	0.6861	2.65	3.03	0.91	0.0634	48.5	26.5
10	Complete fertilizer minus K	6.63	1941	88.7	0.0366	0.7104	3.41	3.05	0.87	0.0480	45.1	23.2
14	Complete fertilizer minus P	6.67	2034	88.9	0.0303	0.6163	3.09	3.05	0.88	0.0544	47.3	23.2
18	None	6.07	1729	88.8	0.0263	0.4547	2.78	3.05	0.89	0.0554	44.1	25.4

TABLE 16.—Wealthy, East Orchard, August 15, 1929

Row and tree	Treatment—Lb. $NaNO_3$ per tree	Weight 15 fruits gm.	Per cent moisture	Per cent nitrogen	Nitrogen per 15 fruits gm.
18- 3	None	2493	87.2	0.0273	0.681
18- 7	None	2525	87.3	0.0250	0.631
18- 9	None	2610	87.7	0.0282	0.733
18-13	None	2784	87.1	0.0361	1.005
18-19	None	2288	85.8	0.0256	0.650
Av. Row 18		2540	87.01	0.0285±0.0020	0.740±0.066
2- 1	5¼	3010	85.4	0.0442	1.330
2- 5	5¼	2910	87.7	0.0332	0.966
2- 7	5¼	2850	87.5	0.0393	1.120
2- 9	5¼	2695	89.3	0.0322	0.868
2-15	5¼	2945	87.1	0.0413	1.126
Av. Row 2		2882	87.42	0.0380±0.0023	1.100±0.079
Difference in favor of Row 2		342	0.41	0.00959	0.360

TABLE 17.—Stayman, East Orchard, July 16, 1929

Row	Treatment $NaNO_3$	Weight 15 fruits gm.	H_2O %	Nitrogen %	Nitrogen Gm. per 15 fruits	Catalase * cc. O_2 5 min.	Sp. Gr. juice	Solids in juice %	pH	Total acid, % as malic
1	5¼ lb.	709	85.6	0.0659	0.467	2.74	1.028	7.04	3.15	0.811
3	1¾ lb.	758	86.0	0.0594	0.450	2.83	1.034	8.50	3.21	0.848
5	Complete fertilizer	754	85.8	0.0759	0.572	3.30	1.035	8.78	3.22	0.851
9	Compl. fert. minus K	701	86.0	0.0596	0.427	3.90	1.035	8.78	3.21	0.830
13	Compl. fert. minus P	671	85.7	0.0691	0.464	2.80	1.034	8.50	3.22	0.837
17	None	687	85.2	0.0556	0.382	2.80	1.034	8.50	3.18	0.823

*Catalase tests unsatisfactory because of variation in the electric current to shaking motor.

TABLE 18.—Stayman, East Orchard, August 6, 1929

Row	Weight 15 fruits gm.	H_2O %	Nitrogen %	Nitrogen Gm. per 15 fruits	Catalase cc. O_2 5 min.	Sp. Gr. juice	Solids in juice %	pH juice	Total acid, % as malic
1	1162	83.5	0.0480	0.558	4.77	1.036	9.0	3.15	0.745
3	1328	85.4	0.0593	0.787	4.73	1.033	8.3	3.18	0.703
5	1172	85.0	0.0528	0.619	4.16	1.034	8.6	3.17	0.729
9	1144	85.0	0.0570	0.652	4.36	1.037	9.2	3.18	0.659
13	948	84.5	0.0419	0.397	4.55	1.036	9.0	3.21	0.698
17	1058	84.7	0.0403	0.426	4.50	1.036	9.0	3.13	0.619

TABLE 19.—Stayman, East Orchard, September 10, 1929

Row	Weight 15 fruits gm.	H_2O %	Nitrogen %	Nitrogen Gm. per 15 fruits
1	2073	83.0	0.0463	0.960
3	1832	83.0	0.0470	0.861
5	1984	82.7	....	....
9	1870	84.2	0.0234	0.437
13	1776	81.0	0.0420	0.746
17	1850	82.8	0.0283	0.524

TABLE 20.—Stayman, Pruning and Fertilizer Block, September 13, 1929

Row	Treatment— $NaNO_3$	Weight 15 fruits Gm.	H_2O %	Nitrogen %	Nitrogen Gm. per 15 fruits	Catalase cc. O_2 5 min.	Catalase leaves seconds for 5 cc. O_2
2	None	1628	83.7	0.0154	0.251	1.79	87
4	2⅛ lb. April 2⅛ lb. June	1810	83.1	0.0177	0.320	2.11	27

TABLE 21.—McIntosh, West Orchard, July 26, 1929

Row	Treatment— $NaNO_3$	Weight 15 fruits gm.	H_2O %	Nitrogen %	Nitrogen Gm. per 15 fruits
3	None	1158	88.1	0.0368	0.426
5	1¾ lb. April	1076	87.7	0.0450	0.484
7	1¾ lb. August	1232	87.2	0.0352	0.434
11	⅞ lb. April ⅞ lb. August	1195	87.7	0.0371	0.443
15	1¾ lb. September	1214	87.7	0.0385	0.467

TABLE 22.—McIntosh, West Orchard, August 9, 1929

Row	Weight 15 fruits gm.	H_2O %	Nitrogen %	Nitrogen Gm. per 15 fruits
3	1702	87.5	0.0335	0.570
5	1532	87.4	0.0419	0.642
7	1592	86.4	0.0389	0.619
11	1654	88.0	0.0437	0.723
15	1397	88.0	0.0428	0.598

TABLE 23.—Stayman Block, Sampled from Storage

Row and tree	Treatment—Lb. $NaNO_3$ per tree	November 21, 1928: Nitrogen, per cent: Insoluble	November 21, 1928: Nitrogen, per cent: Soluble	November 21, 1928: Nitrogen, per cent: Total	H_2O %	January 12, 1929: Soluble pectin as gm. Ca pectate per 100 gm.
A	1¾	0.0228	0.00336	0.0262	86.44	0.275
E 1	3	0.0272	0.00756	0.0348	86.44	0.268
E 5	14	....	....	....	....	0.266

TABLE 24.—Jonathan, West Orchard, Sampled from Storage

Row	Treatment—Lb. $NaNO_3$ per tree	November 24, 1928: Nitrogen, per cent: Insoluble	November 24, 1928: Nitrogen, per cent: Soluble	November 24, 1928: Nitrogen, per cent: Total	November 24, 1928: H_2O %	November 24, 1928: Soluble pectin as gm. Ca pectate per 100 gm.	January 12, 1929: Soluble pectin as gm. Ca pectate per 100 gm.
3	None	0.0268	0.00840	0.0352	88.6	0.240	0.296
7	1¾ April	0.0294	0.00560	0.0350	87.3	0.272	0.242
11	1¾ August	0.0316	0.00954	0.0411	86.0	0.256	0.352
13	⅞ April ⅞ August	0.0303	0.00727	0.0376	86.8	0.232	0.334

TABLE 25.—Grimes, West Orchard, Sampled from Storage

Row	Treatment— Lb. $NaNO_3$ per tree	November 20, 1928					January 12, 1929
		Nitrogen, per cent			H_2O %	Soluble pectin as gm. Ca pectate per 100 gm.	Soluble pectin as gm. Ca pectate per 100 gm.
		Insoluble	Soluble	Total			
3	None	0.0308	0.01007	0.0409	87.7	0.254	0.372
7	1¾ April	0.0336	0.00895	0.0425	87.4	0.292	0.378
11	1¾ August	0.0329	0.00925	0.0421	86.8	0.316	0.389
13	⅞ April ⅞ August	0.0374	0.01204	0.0494	87.5	0.252	0.375

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